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ABSTRACT

This publication details the particulate matter emissions test procedure that is applicable for conducting compliance tests for fuel burning units required to be tested under Sub-section 7 of Regulation II (1972) as established by the State of West Virginia Air Pollution Control Commission. The testing procedure is divided into five parts: General, Sampling Site Criteria, Sampling Method, Measurement Techniques and Equipment, and Computations and Data Analysis. The testing procedure is preceded by pertinent tables, illustrations, definitions, and symbols. Appendixes containing test report forms and a bibliography supplement this testing procedure. (BT)

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STATE OF WEST VIRGINIA

AIR POLLUTION CONTROL COMMISSION

TP-2

PARTICULATE MATTER STACK EMISSION

COMPLIANCE TEST PROCEDURE

FOR

FUEL BURNING UNITS

SE 017 038

State of West Virginia
Air Pollution Control Commission
1558 Washington Street, East
Charleston, West Virginia 25311

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FOREWORD

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Applicability:

This particulate matter emissions test procedure is applicable for conducting compliance tests for fuel burning units required to be tested under Sub-section 7 of Regulation II (1972) - "To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers". The object of the test is to establish the compliance (of the owners/or operators) of such sources with the particulate matter weight emission standards of that regulation.

This test procedure is applicable for determining the particulate matter emission rate(s) from other sources only as the Commission may designate and with such modifications and stipulations as the Commission deems appropriate.

Brief Description of Procedure:

The focal point of this compliance test procedure is the stack or duct which vents combustion gas and particulate matter from one or more similar fuel burning units into the open air.

Three (3) complete and separate determinations of the total particulate matter emission rate through the test stack or duct are required within one seven (7) day period. During the sample extraction periods, the fuel burning unit, or group of similar units, vented by the test stack or duct is to be operated at or above its normal maximum operating load, burning fuel or a combination of fuels representative of the unit(s) normal operation.

Near isokinetic extraction of samples is required from a minimum of twelve (12) sampling points for all but very small sampling planes. Sampling site and sampling point locations are specified.

The in-stack gas velocity and temperature are to be monitored simultaneously with the extraction of the samples. The in-stack velocity is to be monitored with a calibrated Type S pitot tube or equivalent. The particulate matter is to be separated from the sampled gas, at or about stack temperature with a primary filter of specified efficiency and weighed to the nearest 0.1 milligram. Either an in-stack or an out-of-stack filter

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assembly may be used, provided the temperature requirement is met for both the filter and all particulate matter sample contact surfaces prior to the primary filter. The total particulate matter sample weight is to include both the particulate collected by the filter and prefilter, if used, and the particulate obtained by appropriate acetone cleaning of all particulate matter sample contact surfaces prior to the primary filter. Various types of prefilters may be used with the primary filter provided they meet the specified weight stability criteria. In-stack moisture is to be determined by a condenser/absorber method. An Orsat analysis of the sampled effluent gas stream is required. Fuel samples are required for solid or liquid fuel fired during the test runs.

Three methods of determining the heat input to the test unit(s) are prescribed. Data is to be provided using a combination of two of the three methods; each as a check on the other.

The test result is the arithmetic mean of the particulate matter emission rates of the three (3) separate test runs, each of which was conducted in accordance with the requirements of this procedure.

Test report forms on which to submit the test results and supporting data, are available from the Commission on request.

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DEFINITIONS

D. 01. "Commission" shall mean the West Virginia Air Pollution Control Commission.

D. 02. "Director" shall mean the director of the West Virginia Air Pollution Control Commission.

D. 03. "Person" shall mean any and all persons, natural or artificial, including any municipal, public or private corporation organized or existing under the laws of this or any other state or country, and any firm, partnership, or association of whatever nature.

D. 04. "Owner/Operator" shall mean the person responsible for the compliance of the fuel burning units with the provisions of Regulation II (1972).

D. 05. "Test Supervisor" shall mean the person, qualified by experience or education, who is charged with supervising the stack test. This person is responsible for insuring the validity and correctness of the submitted test results.

D. 06. "Process Observer" shall mean the person, under the direction of the test supervisor, who is charged with monitoring and/or obtaining the required heat input and fuel use data for the test runs.

D. 07. "Laboratory Official" shall mean the person, qualified by experience or education, who is charged with overseeing or conducting the laboratory analysis of the collected samples. This person is responsible for insuring the accuracy and validity of the laboratory results.

D. 08. "Plant" shall mean and include all fuel burning units, source operations, equipment, and grounds utilized in an integral complex.

D. 09. "Fuel Burning Unit" shall mean and include any furnace, boiler apparatus, device, mechanism, stack or structure used in the process of burning fuel or other combustible material for the primary purpose of producing heat or power by indirect heat transfer. For the purposes of this procedure, all fuel burning units are classified in the following categories:

a. Type 'a' shall mean any fuel burning unit which has as its primary purpose the generation of steam or other vapor to produce electric power for sale.

b. Type 'b' shall mean any fuel burning unit not classified as a Type 'a' or Type 'c' unit such as industrial pulverized-fuel-fired furnaces, cyclone furnaces, gas-fired and liquid-fuel-fired units.

c. Type 'c' shall mean any hand-fired or stoker-fired fuel burning unit not classified as a Type 'a' unit.

D. 10. "Similar Units" shall mean all Type 'a', or all Type 'b', or all Type 'c' fuel burning units located at one plant.

D. 11. "Fuel" shall mean any form of combustible matter (solid, liquid, vapor, or gas) that is used as a source of heat.

D. 12. "Control Equipment" shall mean any equipment used for collecting or confining particulate matter for the purpose of preventing or reducing the emission of this air pollutant into the open air.

D. 13. "Stack" shall mean, but not be limited to, any duct, control equipment exhaust, or similar apparatus, which vents gases and/or particulate matter into the open air.

D. 14. "Discharge Point" shall mean the point at which particulate matter is released from a stack into the open air.

D. 15. "Particulate Matter" shall mean any material except uncombined water that exists in a finely divided form as a liquid or solid.

D. 16. "Heat Input" shall mean the average rate of heat release from all fuels fired in all similar units vented by the test stack during the test run period.

a. 'Design Heat Input (DHI)' shall mean the heat input level (in MM Btu/hr) for which an individual fuel burning unit has been designed to be operated during continuous operation.

b. 'Total Design Heat Inputs (TDHI)' shall mean the sum of the design heat inputs for all similar units located at one plant.

c. 'Normal Maximum Operating Load (NMOL)' shall mean the sum of the Design Heat Input levels (in MM Btu/hr) of the similar unit(s) vented by the test stack, unless the owner/operator has elected to operate one or more of the similar units vented by the test stack at or below a specified percentage of its Design Heat Input level as part of a compliance program officially accepted by the Commission. In such event, the NMOL shall be the sum of the Design Heat Input levels or fractions thereof as appropriate (i. e., NMOL = 0. 75 DHI_1 + DHI_2).

D. 17. "Normal Operation" when used in the context of fuel quality and combinations fired, shall mean the type, quality, and combination of fuel(s) fired which is representative of the fuel or fuel combination fired, in the unit(s) tested, over a reasonable period prior to the test, and the fuel or fuel combination which might reasonably be expected to continue to be fired in this unit after the test. If the type fuel, quality or combination used in the unit is variable, use the type, quality, and/or combination fired in day-to-day operation which can reasonably be expected to produce the greatest particulate matter loading to the control equipment (i. e., if coal is fired eight months out of the year and gas is fired four months out of the year, coal is to be burned during the test).

D. 18. "ASTM" shall mean American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

D. 19. "Sampling Plane" shall mean the imaginary plane located perpendicular to the gas flow in the duct at the place selected for the extraction of the required samples.

D. 20. "Probe" shall mean the part of the pitobe assembly (nozzle, sample tube, pitot tube, filter holder(s), sensor(s)), which precedes the last filter in the sampling train and conveys the sample gas and particulate matter from the nozzle inlet to the last filter disc used for collecting stack particulate matter.

D. 21. "DOP" shall mean Dioctyl Phthalate: a plasticizer, the smoke of which is used in ASTM filter efficiency tests.

D. 22. "Primary Filter" shall mean the last filter used in the sampling train to separate the particulate matter sample from the sampled stack gas.

D. 23. "Prefilter" shall mean a filter used in the sampling train prior to the primary filter for the purpose of reducing the particulate matter build-up on the primary filter.

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SYMBOLS

Ab	=	(Sd) x (Va). Ab is the estimate of the grams of solids in the acetone wash volume used, prior to use
AFG	=	total weight of stack gas discharged through test stack (in lbs) minus moisture attributable to sources other than the combustion of fuel in tested unit
AFGo	=	total weight of stack gas vented through the test stack during the test period (in lbs) which is attributable to the burning of all fuels but the one not metered
amp	=	ampere, unit measuring electric current
An	=	cross-sectional area of the sampling nozzle (in ft^2)
As	=	cross-sectional area of the sampling plane (in ft^2)
ASTM	=	American Society for Testing and Materials
B	=	percent moisture in the sampled gas, by volume, on a wet basis, divided by 100
B	=	$W \div [(374\ Pm)(Vm)/(Tm + 460)) + W]$
Ba	=	percent (by volume) moisture in the ambient air as determined by a wet-bulb and dry-bulb thermometer and a psychrometric chart for air-water mixtures at 29.92 inches of Hg
BE	=	the boiler thermal efficiency in percent
C	=	453.592 grams/pound
^oC	=	degrees Centigrade
C_f	=	theoretical air conversion constant for the particular type fuel burned (page 5-13)
cfm	=	cubic feet per minute
ck	=	checked
Co	=	0.07492 lb/ft^3 density of air at 70 ^oF; 29.92 in Hg
CO	=	carbon monoxide

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CO_2	=	carbon dioxide
d	=	diameter of nozzle (in inches)
d. a. f.	=	dry ash free basis
DGR	=	dry gas meter reading: the sample gas volume meter reading at meter conditions, in cubic feet
ΔDGR	=	difference between 2 consecutive DGR's, the volume sampled at each sampling point, in cubic feet
DOP	=	dioctyl phthalate
EA	=	excess air fraction
Fi	=	quantity of each fuel fired in a fuel burning unit during the total test run period (in appropriate units)
^oF	=	degrees Fahrenheit
ft^3	=	cubic feet
Fp	=	combined correction factor for units and pitot tube deviation
ft/min	=	feet per minute
gm	=	grams
Gd	=	gas density correction factor (apparent molecular weight of stack gas/29)
Δ H	=	pitot tube differential reading (in inches H_2O)
hi	=	average enthalpy of steam entering the boiler of the fuel burning unit (Btu/lb)
HI	=	heat input per fuel burning unit(s) (in 10^6 Btu per hour)
ho	=	average enthalpy of steam leaving the boiler of the fuel burning unit (in Btu/lb)
Δ Hp	=	indicated differential pressure when the test pitot tube is used at the calibration point

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ΔHs	=	indicated differential pressure when the standard pitot tube is used at the calibration point
H_2S	=	hydrogen sulfide
HV_i	=	average Btu value of each fuel used on an as fired basis, in appropriate units (Btu/lb, Btu/gal, etc.)
HV_f	=	heating value of the fuel on an as fired basis (in Btu/lb)
in Hg	=	inches of mercury, pressure
ISKp	=	point isokinetic factor, ratio of the actual sample volume to the isokinetic sample volume
ISKo	=	overall isokinetic factor, ratio of total actual sample volume (Qm) to the total isokinetic sample volume (Qo), both volumes adjusted to standard conditions
%ISK	=	100 (ISKo - 1)
Kp	=	coefficient of deviation of the Type S pitot tube used in sampling determined by calibration
Ks	=	coefficient of deviation for a standard pitot tube
lbs	=	pounds
m	=	Mo - s/2, particulate matter collected (gram)
Ma	=	particulate matter obtained from the evaporation of the acetone washings, in grams
Mf	=	particulate matter collected by filter(s) (in grams)
mf	=	average mass flow rate of steam through the boiler (in lb/hr)
mg	=	milligram
ml	=	milliliter
Mo	=	Mf + Ma - Ab (in grams), indicated weight of particulate matter collected by the sampling train
n	=	number of items in a set of related items
N_2	=	nitrogen
Np	=	number of sampling points required by the area ratio criteria

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θ	=	sum of all extraction times at all points sampled per run (min.)
Pb	=	atmospheric pressure (in. Hg)
Pcf	=	ash fraction of the non-metered fuel, on an as fired basis
Pf	=	ash fraction in fuel "f" on an as fired basis
Pm	=	absolute pressure of gas at meter (in. Hg)
$\overline{Pm}$	=	average absolute pressure of the sampled gas at meter conditions for the test run (in. Hg)
Ps	=	absolute pressure of gas in stack at sampling plane
qm	=	actual sample volume for each sample point adjusted to 70 ^{o}F and 29.92 in Hg (in ft^3)
Qm	=	sum of all qm for each test run (in ft^3)
qo	=	volume of sampled gas for each point if isokinetic conditions were maintained, adjusted to 70 ^{o}F and 29.92 in Hg (in ft^3)
Qo	=	sum of all qo for each test run (in ft^3)
r	=	s/Mo, relative uncertainty in the true value of m, the particulate matter sample weight
s	=	change in weight of the control filters (grams)
Sd	=	solids found in acetone blank (gm/ml)
SO_2	=	sulfur dioxide
π	=	pi, 3.1416
Δt	=	elapsed time at each sampling point, minutes
THA_f	=	theoretical air requirements of each fuel burned (lbs-air/lbs-fuel)
T_f	=	temperature of the primary out-of-stack filter holder, when used, ^{o}F
Tm	=	temperature of gas sample at volume meter for each point, ^{o}F

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$\overline{Tm}$	=	average temperature of gas sample at volume meter for test run, ^{o}F
Ts	=	stack gas temperature, ^{o}F
V	=	volts
Va	=	volume of acetone wash, ml
Vac	=	vacuum (inches of mercury)
Vm	=	sum of all ΔDGR for the test run (ft^3)
V. M.	=	volatile matter (in coal)
W	=	Wc + Wd (grams), amount of H_2O removed from the sampled gas
w	=	1/(1 - B), ratio of wet gas volume to dry gas volume
Wa	=	lbs of water vapor present in the effluent stack gas due to moisture in the ambient air
Was	=	lbs of water present in the total volume of stack gas after a scrubber
Wbs	=	lbs of water present in the total volume of stack gas before a scrubber
Wc	=	amount of water collected in the condenser (grams)
W_{cf}	=	weight of the non-metered fuel fired (lbs)
Wd	=	amount of water collected by the drying agent in the absorber (grams)
wf	=	total measured weight of fuel "f" fired in all fuel burning units vented by test stack during test period (in lbs)
Wh	=	Ws +Wa, total water present in stack gas, due to sources other than the combustion of fuel(s), in lbs
Ws	=	total water vapor added to the effluent stack gas stream during the test run by a scrubber, in lbs

Xcf	=	X_f for the non-metered fuel
Xf	=	THA_f (1+ EA) + 1, the number of pounds of flue gas and ash per pound of fuel burned
#	=	lbs, pounds
%	=	percent

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PART I. GENERAL

1.00. Request for Test Data/General Requirements.

1.01. Become familiar with the requirements of Regulation II (1972) - "To Prevent and Control Particulate Air Pollution From Combustion of Fuel in Indirect Heat Exchangers", and the requirements of this test procedure before conducting the compliance test.

Review all forms, equations, and definitions.

Questions of interpretation, applicability, or exception, are to be resolved with the Director or his designee prior to conducting the test.

1.02. When a compliance test conducted in accordance with this procedure is required, the owner or operator of the affected unit(s) will be notified in writing by the Director or his designee. The notice will prescribe the following:

a. the unit(s) to be tested;
b. the identification number to be assigned to the test;
c. the date by which the test is to be completed and the test report submitted; and
d. the person, if other than the Director, to whom the test report is to be submitted, and with whom questions concerning the test procedure may be resolved.

Test report forms (see Appendix) for filing the results of the compliance test are available from the Commission on request.

1.03. The result of each requested compliance test is to be the arithmetic average of three (3) complete sampling runs conducted, within one seven (7) day period, as prescribed by this procedure.

Subject to the provision of Section 3.00 of this Part, Minor Exceptions, a complete sampling run is one complete determination of the total particulate matter emission rate through the test stack for which:

a. the minimum total sampling time is two (2) hours;
b. the minimum total sample volume is sixty (60) cubic feet adjusted to $70^{o}F$ and 29.92 inches of Hg.

c. the composite particulate matter sample is extracted from the duct or stack at a location and from the number of sampling points prescribed by PART II: SAMPLING SITE CRITERIA, and PART III: SAMPLING METHOD;

d. the sampling equipment and its method of operation meet the criteria and requirements of PART IV: MEASUREMENT TECHNIQUES AND EQUIPMENT;

e. the overall sampling rate is within ± 10% of the overall isokinetic sampling rate, computed as specified in PART V: COMPUTATIONS AND DATA ANALYSIS; and for which the isokinetic ratio for each individual sampling point does not vary greatly from the overall ratio;

f. the stack gas components data is provided (see Part IV, Section 2.03, Orsat Analysis);

g. the other provisions of this procedure are met and sufficient heat input and fuel quality data is provided to verify that the requirements of Section 2.00 below are met; and

h. sufficient commentary is provided with the submitted test report forms to allow the Director or his designee to evaluate the reported test results and the conditions under which they were obtained.

2.00. Unit Load and Fuel Quality Requirements.

All compliance test runs, which are to be included in the test result for a unit or a specified number of similar units, shall be conducted while the unit or group of similar units is operated at or above the normal maximum operating load for the specified unit or group of units; while fuel or combinations of fuel representative of normal operation are being burned; and under such other relevant conditions as the Director may specify based on representative performance of the specified units.

3.00. Minor Exceptions.

3.01. In the interest of practicality the Director or his designee may allow minor exceptions, not related to test site safety, to the specifications of this procedure, if such person concludes that in a particular case, the granting of such exception would not invalidate the test results. If such exceptions are granted, alternate specifications may be prescribed.

3.02. If an exception as described above is granted, the scope of the exception and any alternative specification prescribed will be recorded in a letter of exception signed by the authorizing official. A copy of such letter of exception shall be attached to the test report.

PART II. SAMPLING SITE CRITERIA

1.00. Sampling Plane Location.

1.01. The sampling plane is to be located in a straight run of duct or stack on the discharge side of any control equipment used.

1.02. All combustion gases, minus removed pollutant materials, generated in the unit or group of similar units being tested, must pass through the sampling plane before being discharged to the open air.

1.03. If the products of combustion from more than one type of fuel burning unit are vented to the open air through one discharge point, sampling planes are to be located prior to this discharge point in such a manner as to allow the determination of the particulate emission rate(s) attributable to each of the different type units or groups of units.

1.04. Each sampling plane is to be located at least two (2) stack diameters downstream from any bend or obstruction in the gas stream and at least one-half ($\frac{1}{2}$) stack diameter upstream from any such disturbance (including the stack outlet). The gas flow throughout the sampling plane is to be all in one direction. For the purposes of this procedure the equivalent stack or duct diameter for a rectangular stack or duct is determined from the following equation:

$$\text{Equivalent Diameter} = 2\left[\frac{(\text{length}) \times (\text{width})}{(\text{length}) + (\text{width})}\right]$$

Recommendation: It is recommended that whenever feasible the sampling plane be located at least eight (8) stack diameters downstream from any bend or disturbance and at least two (2) stack diameters upstream from any disturbance to improve the flow conditions at the sample site; and that sampling planes with a cross-sectional area of greater than 300 square feet be avoided as much as possible to minimize the number of sampling points. It is further recommended that when possible, test sites be selected which allow easy access to, and installation of, sampling ports on both sides of large rectangular ducts to allow the use of shorter probes.

1.05. Traversing up into a horizontal duct is to be avoided. Accessing sampling points from the top of a horizontal duct is allowable, but should be avoided when possible.

1.06. Sufficient room is to be provided around the test site for the safe and efficient operation of the test equipment.

1.07. If railings are required around the test site for the safety of test personnel, the railings are to be constructed in such a manner as to avoid interference with the probe assembly movements into and out of the stack.

1.08. Provisions are to be made to mount an equipment hoist (block and tackle) and the pitobe assembly support rail(s), rack, or platform when required.

1.09. A source of 110 V, 30 amp, 60 cycle, electrical service is to be provided near the test site to power the test equipment.

2.00. Sampling Port Size and Location.

2.01. The number and location of sampling ports depends upon the number of required sampling points.

2.02. Determine the minimum required number of sampling points for each sampling plane, using the data and specifications of PART III: SAMPLING METHOD.

2.03. Select and locate the sampling ports so each required sampling point can be accessed directly through a port with the probe assembly positioned perpendicular to the stack or duct wall. Circular ducts require a minimum of two (2) mutually perpendicular ports. Provide four ports when feasible to minimize the length of probe required. For the same reason, when feasible provide ports on both sides of rectangular ducts when a horizontal traverse length of greater than ten (10) feet is required to reach any of the sampling points from one side of the duct.

2.04. Provide the required number of ports, with a minimum inside port diameter of three and one half ($3\frac{1}{2}$) inches, which extend at least three (3) inches beyond the outside duct or stack wall, and which are mounted flush with the inside duct wall. If the ports, for structural reasons, cannot be mounted flush with the

inside duct wall(s), allow the ports to extend into the stack gas flow no further than necessary to securely install the port. Each port is to be capable of safely supporting the load imposed on it by the sampling train support device(s), when used.

2.05. Locate the selected number of ports at a convenient distance from the platform (floor, catwalk, etc.) from which the test team will operate the sampling probe.

2.06. Install the ports perpendicular to the walls of the stack or duct.

3.00. Sampling Site Safety.

3.01. The sampling site shall be provided and equipped in such a manner as to allow safe access to the test site and safe operation of the test equipment. Equipment such as scaffolding, railings, ladder, and catwalks, are to comply with generally accepted good safety practices.

3.02. All electrically conductive equipment inserted into the downstream side of an electrostatic precipitator is to be carefully grounded, such that the equipment remains grounded while inserted in the duct, and such that the ground wires do not interfere with the testing procedure.

PART III: SAMPLING METHOD

1.00. Number of Sampling Points.

The minimum numbers of sampling points per sampling plane is determined from the three (3) criteria prescribed in 1.01 below, and the modification prescribed in 1.02, when it applies.

1.01. Subject to the provision of 1.02 below, the minimum required number of sampling points is the greatest number required by any one of the criteria listed below:

a. The minimum number of sampling points for each sampling plane is to be twelve (12) points;

b. The minimum number of sampling points for each sampling plane is to be no less than the number of points (nearest even number for a rectangular duct; nearest multiple of four (4) for a circular duct) specified by the number of duct diameters from the upstream distance (A) or the downstream distance (B) to the sampling plane, from any flow disturbance, as specified in Figure 3-1, Determination of the Required Number of Sampling Points - Disturbance Criteria; or

c. The minimum number of sampling points for each sampling plane is to be no less than the value Np in the following equation adjusted to the nearest even number for a rectangular duct or the nearest multiple of four (4) for a circular duct:

$$Np = As/12$$

where As is equal to the sampling plane cross-sectional area in square feet.

1.02. For a sampling plane with a diameter or equivalent diameter of less than two (2) feet, the minimum required number of sampling points is two-thirds (2/3) the number of required points as determined by Section 1.01 above, adjusted to the nearest even number or multiple of four (4) as above.

2.00. Location of Sampling Points.

2.01. Circular ducts. The location of sampling points for circular ducts is to be similar to that illustrated in Figure 3-2, Cross Section of Circular Stack Showing Location of Sampling Points on Perpendicular Diameters, and as prescribed in Table 3-1, Location of Sampling Points in Circular Ducts.

2.02. Rectangular ducts. The location of sampling points for rectangular ducts is to be similar to that illustrated in Figure 3-3, Cross Section of Rectangular Stack Divided into Equal Areas, with Sampling Point at Centroid of Each Area. Divide the sampling plane into a number of equal areas, equal to the number of sampling points which are required. Each area is to be as nearly square as possible, but in no case having a length to width ratio greater than 2:1. Locate the sampling points at the centroid of each equal area.

2.03. Under no condition is any sampling point to be selected within one (1) inch of the duct wall.

3.00. Sampling Time at Each Point.

3.01. Samples are to be extracted from each required sampling point for a minimum of five (5) minutes total at each point.

3.02. Samples are to be extracted from each required sampling point for equal time periods within $\pm$ 30 seconds.

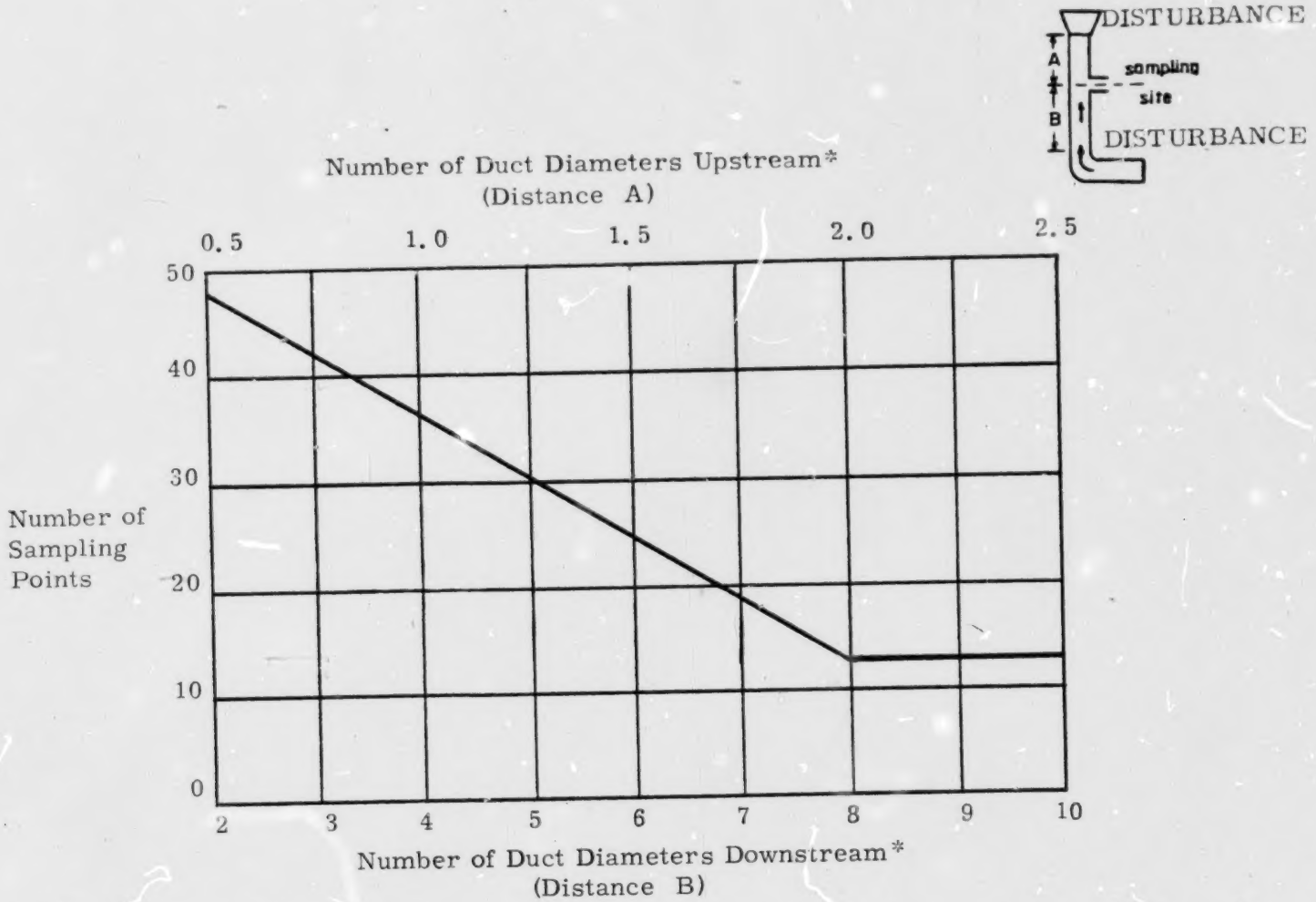


Figure 3-1. Determination of the Required Number of Sampling Points - Disturbance Criteria

* From the point of any type of disturbance (bend, expansion, contraction, etc.)

Reference: Federal Register, December, 1971.

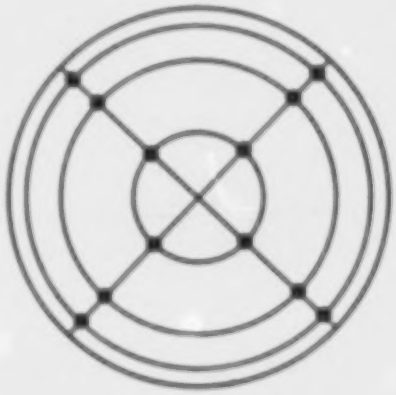


Figure 3-2. Cross Section of Circular Stack Showing Location of Sampling Points on Perpendicular Diameters

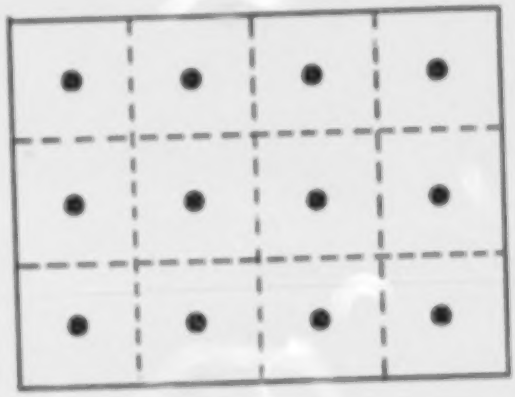


Figure 3-3. Cross Section of Rectangular Stack Divided into Equal Areas,* with Sampling Points at Centroid of Each Area

*For non-circular stacks, the equal areas should be as nearly square as possible.

Table 3-1. Location of Sampling Points in Circular Stacks

(Percent of Stack Diameter from Inside Wall to Sampling Point)

Sampling Point Number on a Diameter	Number of Sampling Points on a Diameter									
	6	8	10	12	14	16	18	20	22	24
1	4.4	3.3	2.5	2.1	2.0	2.0	2.0	2.0	2.0	2.0
2	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5	85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6	95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7		89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8		96.7	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9			91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10			97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11				93.3	85.4	78.0	70.4	61.2	39.3	32.3
12				97.9	90.1	83.1	76.4	69.4	60.7	39.8
13					94.3	87.5	81.2	75.0	68.5	60.2
14					98.0	91.5	85.4	79.6	73.9	67.7
15						95.1	89.1	83.5	78.2	72.8
16						98.0	92.5	87.1	82.0	77.0
17							95.6	90.3	85.4	80.6
18							98.0	93.3	88.4	83.9
19								96.1	91.3	86.8
20								98.0	94.0	89.5
21									96.5	92.1
22									98.0	94.5
23										96.8
24										98.0

Reference: Federal Register, December, 1971, (modified).

PART IV: MEASUREMENT TECHNIQUES AND EQUIPMENT

1.00. Dimensional Measurements.

1.01. Sampling Plane Dimensions.

a. Measure the inside length and width of a rectangular cross section and the diameter of a circular cross section to the nearest inch.

b. Check the inside of the stack for loose scale and deposit build-up. Note these conditions on Form SSD: Sampling Site Data Sheet. If deposit or build-up is present, the inside duct dimensions are to be the effective inside dimensions.

c. In determining the depth of a horizontal duct, special care is needed due to the possibility of a deposit of loose ash on the bottom of the duct. A recommended method is to probe the duct depth with a Type S pitot tube, noting the indicated velocity head pressure differential toward the bottom of the duct. If the pressure differential drops to zero before the probe touches the bottom of the duct, the depth to the point of zero pressure differential (velocity) is to be used as the effective depth.

d. On Form SSD, construct a scale drawing with dimensions of the sampling plane cross section showing the duct walls, sampling ports, and scale or deposit build-up, as appropriate. Compute the sampling plane cross-sectional area (As) in square feet. Record this value on Form SSD and Form TD: Test Run Data Sheet.

1.02. Sampling Plane Location.

a. Check the distance to the nearest upstream and downstream disturbance (bend, baffles, etc.) from the sampling plane location. It is recommended that a physical inspection of the ductwork be made with the aid of plant drawings, when available.

b. On Form SSD, sketch the general layout and duct arrangement adjacent to the sampling plane, showing

appropriate dimensions, bends, obstructions, baffles, changes in cross-sectional area, etc. Also record the stack diameter or equivalent stack diameter (see PART II, Sub-section 1.04), and the number of stack diameters to the nearest upstream and downstream disturbance.

1.03. Sampling Point Location.

a. From the data obtained in Sections 1.01 and 1.02 above, and the sampling point criteria in PART III: SAMPLING METHOD, determine the required number and arrangement of sample extraction points, and select the sample extraction time (Δt) for each sampling point.

b. Indicate and number these points on the sampling plane cross section drawing required on Form SSD: Sampling Site Data Sheet. Record the point sampling time selected.

c. Determine the order (sequence) in which these points will be sampled and enter the point number in sequence on Form TD: Test Run Data Sheet. If the point sampling time selected is greater than ten (10) minutes, use two lines on Form TD for each point, recording the required data at both the midpoint and end of the interval. Leave a blank line between each set of port points on this form to allow space for necessary data when transferring the pitobe assembly from one port to the next (e.g., time and dry gas meter readings). In selecting the sampling point order, begin with the farthest point accessible from the first port and move back toward the port before moving to the next selected port and repeating the process.

d. Compute the distance from each sampling point to the outside edge of the sampling port. Lay off these distances from the sample nozzle inlet back along the sampling tube (pitobe assembly) and mark each distance.

e. Compute the distance from the outside edge of the ports to the opposite side of the duct or the point of scale or deposit build-up, whichever is less. Subtract 2% or one (1) inch, whichever is greater, from this length; lay off and mark this length (the maximum safe traverse depth - M.S.D.) on the probe as above.

f. In conducting the sampling traverses do not insert the probe into the stack beyond the M.S.D. or allow the nozzle tip to touch the sampling ports, as either event can cause the pick-up of loose deposits which do not represent the actual particulate matter stack emission rate.

1.04. Sampling Nozzle Diameter.

a. From a preliminary velocity traverse or other data on the duct velocities, select a nozzle diameter which will allow a minimum total wet sample volume (Qm) for the run of 60 ft^3 (adjusted to 70 ^oF and 29.92 inches of Hg), without the face velocity through the fiber filter media exceeding 100 ft/min for any sampling point. Use the same size nozzle (diameter) for all points in each run. Do not use a nozzle with an inside diameter of less than 0.250 inches.

b. Measure the inside diameter of the selected sampling nozzle to the nearest five/one thousandth of an inch using suitable precision instrument(s). Compute the sampling nozzle cross-sectional area from this measurement and record this value on Form TD: Test Run Data Sheet:

$$An = \left[\frac{\pi}{4} \cdot \frac{d^2}{144}\right] = \left[\frac{d^2}{576}\right]$$

An = nozzle cross-sectional area in square feet

π = pi = 3.1416----

d = measured nozzle diameter in inches

2.00. Sample Extractions.

2.01. Extraction Equipment. The composite sample is to be extracted from the duct or stack at the points determined in Section 1.00 above, with a combined system of sensors, collectors, probe, and sample tubes termed a sampling train. The sampling train is to be composed of the components itemized on the following pages.

Sampling Train Components. (See Figure 4-1 (a) and (b), Sampling Train Schematics.

1. Nozzle. The sampling nozzle is to be smooth and circular in cross section with the outer edges of the nozzle narrowing to a sharp edge at the nozzle inlet. See Figure 4-2, Sampling Nozzle.

2. Filter Holder Assemblies. See Figure 4-3, Filter Holder Assemblies. Either an in-stack or an out-of-stack filter holder assembly may be used. In either case particular attention is to be given to insure that the fiber filter discs are securely sealed and properly supported in the filter holder used. The sealing mechanism used to seal the fiber filter(s) is to be capable of sealing an impervious leak test disc securely enough to hold the leak rate around the test disc to no more than 0.02 cfm at 25 inches of Hg vacuum. The filter holder assemblies are to be made from non-corrosive materials such as glass, 316 - stainless steel, Incoloy 825, etc.

   a. In-stack filter holder. The filter holder assembly may provide for the use of a preweighed ceramic or equivalent type thimble prefilter in addition to the primary filter. The holder is to be small enough in diameter to be easily passed through a three and one-half ($3\frac{1}{2}$) inch port with the attached pitot tube and stack temperature sensor.

   b. Out-of-stack filter holder. A glass-cyclone or equivalent type precollector may be used with the out-of-stack filter holder provided both devices and all particulate matter sample contact surfaces prior to the fiber filter, and the filter, are maintained at or about stack temperature.

3. Fiber Filter Media. The primary filter media used is to be a fiberglass mat filter disc certified to be at least 99% efficient in collecting 0.3 micron DOP (Dioctyl Phthalate) smoke, or a media of equivalent properties and efficiency. This filter is to be the last particulate matter collection device used in the sampling train.

4. Pitobe.

   a. The pitobe assembly is composed of:

(1) A corrosion resistant sample tube or probe, and connected nozzle, through which the carrier gas is extracted from the stack.

(2) A calibrated type S pitot tube or equivalent which is securely attached to the probe or sample tube in a manner which allows the head of the pitot tube to be posi ioned adjacent to the sampling nozzle, with both the nozzle inlet and the upstream inlet of the pitot tube facing directly into the gas stream.

(3) A temperature sensing device attached to the sample or pitot tube in a manner that the temperatu e near the nozzle inlet can be measured.

b. The pitobe assembly is to be long enough to position the nozzle at each required sampling point, without the assembly deflecting more than three-eighths (3/8) inch per foot of assembly length. Long pitobe assemblies may be encased in larger diameter electrical conduit and/or supported near the nozzle connection with in-stack support wires or similar devices. It is also recommended that long pitobe assemblies be mounted on the test stack or duct with the aid of a monorail, sliding rack or other suitable device to allow the operator to efficiently move the assembly from point to point.

c. The pitobe assembly is to be made from non-corrosive materials. When an out-of stack filter is used the inside of the probe or sample tube which conveys the sample gas to the primary filter or prefilter holder assembly is to be a smooth continuous surface capable of being analytically cleaned.

5. Condenser/Absorber.

a. The condenser is to be capable of cooling the sample gas stream to around 70 ^{O}F, and collecting and holding the water condensed during this process.

b. The condenser is to be followed by an absorber-a drying agent cell for removing the remaining moisture. An indicating type of desiccant material

is recommended for the absorber media (e.g., 6-16 mesh silica gel, or granular calcium sulfate).

c. The condenser/absorber assembly may be connected to the end of the sample tube using non-reactive flexible tubing with a wall strength sufficient to withstand a vacuum of 25 inches of Hg without collapsing.

6. Volume Meter.

The condenser/absorber is to be followed by an integrating volume meter equipped with a vacuum and temperature sensor. The meter is to be capable of measuring the dry sample volume within 2%. A dry gas test meter is recommended.

7. Rate Meter.

A rate meter such as an orifice or venturi flow meter is to be incorporated into the sampling train as an operational aid for maintaining isokinetic flow conditions.

8. Vacuum Source and Controls.

a. A plant vacuum source or a vacuum pump may be used, provided 25 inches of Hg vacuum can be achieved with the device and a non-pulsating flow can be maintained.

b. A flow control valve is to be incorporated between the vacuum device and the condenser/absorber.

c. The flow control valve or valve combination is to be capable of readily adjusting and controlling the flow rate to isokinetic conditions.

9. Pitot Tube and Rate Meter Pressure Differential Gauges.

Incline differential manometers or other type differential pressure gauges may be used provided the gauge is capable of indicating the differential pressure to the nearest 0.02 inches of water for the differential guage used with the pitot tube. The accuracy of the gauge used with the rate meter is to be sufficient to allow maintenance of isokinetic conditions.

10. Temperature Meter and Vacuum Gauges.

Temperature meters are to be capable of indicating the stack and volume meter temperature to the nearest 5 °F. The vacuum gauge used with the volume meter is to be capable of indicating the meter vacuum to the nearest 0.5 inch of Hg. If an out-of-stack primary filter is used, temperature sensors are to be provided to monitor the probe outlet temperature and the primary filter holder temperature.

11. Transport Containers.

Clean, protective containers are to be used to transport the prepared filter holders, and condenser/absorber components (when applicable) to and from the test site. Such containers are to be constructed and used in such a manner as to protect these components from breakage, damage or contamination.

2.02. Preparation for Sampling.

a. Pre-survey.

It is highly recommended that a pre-survey of the test site and plant be made prior to conducting the test to determine dimensional values of the ductwork, the range of stack temperatures, moisture and velocities and to obtain other data helpful in planning and conducting the test.

b. Sample Recovery Area.

Select a clean area near the test site for the sample recovery area. Use the sample recovery area to install the selected filter holder assemblies, condenser components (when applicable), and nozzles, and to assemble the major components of the sampling train. After each test run, use this area to recover the collected samples.

c. Sampling Train.

1. Assemble the preweighed primary filters in their filter holders in the laboratory. Prefilters may be assembled at the sample recovery area.

2. The absorber cells are to be filled with the selected drying agent at the laboratory, preweighed to the nearest gram, and sealed for transport to the test site.

3. The condenser may be partially filled with a measured amount of distilled water at the sample recovery area. Record the amount of water to the nearest milliliter (ml). If impingers are used as part of the condenser apparatus, it is recommended that at least four (4) impingers be used per train; each with a volume of at least 600 ml, filling the first two impingers with 100 ml of water each, leaving the third impinger dry, and using the last impinger as a drying agent cell.

4. Calibrate the pitot tube of the pitobe assembly in the configuration in which it will be used during sampling and in the range of velocities for which it will be used. To calibrate the pitot tube, measure the velocity head at some point in a flowing gas stream with both the pitot tube to be used and standard type pitot tube with a known coefficient. Compute the pitot tube coefficient for the tube to be used from the following equation:

$$Kp = Ks \sqrt{\frac{\Delta Hs}{\Delta Hp}}$$

Kp = the coefficient of deviation for the pitot tube to be used

Ks = the coefficient of deviation for the standard pitot tube

Δ Hp = the indicated differential pressure when the test pitot tube is used at the calibration point

Δ Hs = the indicated differential pressure when the standard pitot tube is used at the calibration point

5. After assembling the selected components and positioning the sampling train to begin sampling, leak test the sampling train and check all temperature sensors, pressure sensors, and operational controls. Do not proceed with the test until the leak rate through the sampling train as indicated on the integrating volume meter is less than 0.02 cfm at 15 inches of Hg vacuum.

d. Orsat Sample.

Position the Orsat analyzer (See Section 4.03 of this part) at the test site for a direct analysis of the test stack gas, when feasible. Use a minimum length of sample line. Position one or more non-corrosive sample tubes in the stack with the sample inlet(s) fitted with a prefilter (e.g., glass wool packing) toward the center of the stack but not closer than one (1) foot from the stack or duct wall. Flush the sample line(s) with stack gas and leave connected for sampling. One probe is to be used for the grab samples and the other for the optional integrated sample (if used). See Figures 4-4 Composite Gas Sample Device and Figure 4-5 Orsat Sample Analyzer.

e. Fuel Samples.

It is recommended that the necessary arrangements for obtaining the required fuel samples and heat input data be made during a pre-survey or other convenient time well in advance of conducting the sampling runs.

2.03. Conducting the Sampling Run.

a. General.

1. Follow the point sampling sequence determined under Sub-section 1.03 of this Part and recorded on Form SSD: Sampling Site Data Sheet.

2. Measure and record the in-stack static pressure and the barometric pressure. Check these values at the end of the sampling run or more often if deemed necessary.

b. Sampling Train Operation.

1. Insert the pitobe assembly into the stack. Using the probe markings made under Sub-section 1.03 of this part, position the nozzle inlet pointing directly into the gas flow at the first sampling point. Hold the nozzle steady in this orientation during the extraction interval (time) at each required point.

2. Record on Form TD: Test Run Data Sheet, the time and the initial volume meter reading; activate the vacuum source; adjust the flow through the sampling train to isokinetic conditions. Maintain isokinetic conditions throughout the sampling period. Record the local time to the nearest minute that the sample extraction begins at each point.

3. During the extraction period at each point monitor the:

Stack temperature	Ts
Pitot tube pressure differential	ΔH
Volume meter temperature	Tm
Volume meter vacuum	Vac
Volume meter reading	DGR
Primary filter temperature (if an out-of-stack filter is used)	T_f

Record the value of each in the appropriate column of Form TD at the end of the extraction period before moving to the next point. If the extraction period is longer than 10 minutes, also record the appropriate data at the midpoint of the sampling interval.

4. At the end of the extraction interval at each point, record the actual elapse time (Δt) and ending volume meter reading (DGR) in the appropriate column of Form TD: Test Run Data Sheet.

5. At the end of the extraction interval, move quickly to the next sampling point; readjust the train flow rate to isokinetic conditions, and record the required data.

6. When the pitobe assembly must be removed from the stack and repositioned in the next sampling port, move the assembly with care so as not to introduce

any significant error in the results. After the train has been repositioned at the first point inside the next sampling port, note the time and volume meter reading. Readjust the sampling train flow to isokinetic conditions, and proceed as before. In moving the pitobe assembly, reduce or shut off the gas flow through the sampling train,as appropriate.

7. At the completion of the last extraction interval in the sampling run, carefully remove the pitobe assembly from the stack, draw several cubic feet of clean air through the train, stop the flow through the sampling train, and seal the nozzle.

8. Exercise care in moving the sampling train to the sample recovery area, to minimize the loss of collected sample or gain of extraneous material.

c. Orsat Sample.

1. Three stack gas grab samples are required per hour during the total test run period. A continuous Orsat sample is optional.

2. The grab samples may be obtained in a number of separate containers and returned to the laboratory for analysis,or the grab samples may be drawn directly into the Orsat analyzer at the test site (preferred). See Sections 2.02 and 4.03 of this Part. The continuous Orsat sample may be analyzed at the test site or at the laboratory. In either case, use the procedure prescribed in Sub-section 4.03 of this Part for the sample analysis for CO_2, O_2, CO, and N_2 for both the grab samples and the composite samples (if obtained). See Form TOA: Laboratory Data Sheet (Orsat).

d. Fuel Sample(s)/Heat Input Measurements.

1. Obtain the required fuel samples representative of the fuels being fired during the test run, as specified in Part IV, Sub-section 5.02.

2. Obtain the required heat input data measurements as specified in Section 5.00 of this part, during the test run period.

3.00. Sample Recovery.

a. Sampling Train Components. Exercise care in moving the sampling train components from the test site to the sample recovery areas to minimize the loss of collected sample or the gain of extraneous material. At the sample recovery area:

1. Remove the prefilter from the sampling train. If a ceramic thimble or equivalent was used, the thimble may be placed in a clean, marked, sealed glass jar or equivalent using care not to touch the inside of the thimble. Return the thimble to the laboratory for analysis. If a cyclone precollector was used, wash out the inside of the cyclone and the cyclone catch container with acetone into a clean, marked glass jar or equivalent. Seal this container for transport to the laboratory after the washings described in (3) below are completed.

2. Remove the primary filter holder from the sampling train; seal, and place it in a sample transport container.

3. With the aid of a brush, rubber policeman or other suitable device, wash and clean with acetone (only) all particulate matter sample contact surfaces prior to the primary filter (e.g., nozzle, probe, filter holder, connecting glassware). Deposit these washings in the acetone wash container mentioned in (1) above. Save a portion of the acetone stock used for a blank analysis. Seal the acetone wash container for return to the laboratory.

4. Measure the volume of water collected by the condenser, at the recovery area, to the nearest ml, or seal the condenser for return to the laboratory for measurement. Seal the drying agent cell (absorber) and return it to the laboratory for measurement of the moisture collected by the drying agent to the nearest gram.

5. Record the sampling train component markings and data on Form TD: Test Run Data Sheet and the appropriate Laboratory Data Sheets.

b. Orsat Samples.

If the Orsat samples are not analyzed on site, carefully seal the grab sample containers used and store in a transport container for return to the laboratory.

If a composite Orsat sample was also taken, with an apparatus similar to that illustrated in Figure 4-4 Composite Gas Sample Device, analyze the sample on site, when feasible; if not, seal the sample container at the end of the sampling run, and transport the device to the laboratory with the leveling bottle slightly above the sample bottle to minimize possible contamination of the gas sample during transport due to small leaks around the stopcocks or tubing connections. It is recommended that all of the Orsat samples be analyzed on site whenever feasible.

c. Fuel Samples.

At the completion of the test run seal the required fuel samples in air-tight, water proof containers; mark, and return to the laboratory for analysis.

4.00. Laboratory Measurements.

4.01. Particulate Matter Sample Weight.

a. Filter Holder Assembly Preparation

1. Dry the filter discs to constant weight at 105 ^{o}C; cool the filters to ambient room temperature in a desiccator. Select one filter for a blank analysis and three or more filters for the sampling runs. Weigh each filter in a low humidity room or chamber to the nearest one-tenth (0.1) of a milligram. After weighing, seal each filter in a clean dry filter holder assembly. Record, on Form TLP: Laboratory Data Sheet (Particulate), the assembly numbers or designations, and their respective tare weights.

2. Place the blank primary filter selected, secured in a filter holder, in an oven at or about the expected stack temperature for at least two (2) hours. Cool in a desiccator to room temperature.

remove the filter disc from the filter holder, reweigh the filter to the nearest 0.1 milligram. Record the before and after weights of the filter in the appropriate column of Form TLP: Laboratory Data Sheet (Particulate).

3. After assembly, immediately seal both ends of the prepared test filter holder assemblies, and place the sealed assemblies in a clean sample transport box for transport to the sample recovery area associated with the test site.

4. If ceramic prefilters are used, they are to be preheated in an ignition furnace for at least one hour at 800°C, cooled in a desiccator and each weighed to the nearest 0.1 milligram. Select one thimble for a blank analysis and seal the others; each in a clean, marked, glass jar or equivalent container. Record the thimble tare weights and their identification markings on Form TD: Test Run Data Sheet and Form TLP: Laboratory Data Sheet (Particulate). Secure the blank thimble in a holder and perform a blank analysis for the thimble in the same manner as for the primary filter in (2.) above. Record the data on Form TLP.

b. Collected Particulate Matter Weight.

1. After the filter holder assemblies have been used at the test site and returned to the laboratory, clean the exterior of the sealed filter holder as necessary.

2. Remove the seals from the filter holder assemblies. Carefully disassemble the holders and remove the filter disc(s), placing each disc in a preweighed, marked weighing bottle or equivalent. Remove the prefilter thimble (if used) from its transport container and handle similarly.

3. Wash the inside of the filter holder assemblies with acetone using a small brush, rubber policeman, and/or spatula as necessary to remove all adhered particulate matter. Deposit the particulate matter washings for each run into the washings sample

container for that run. See Part IV, Sub-section 3.00 (a) (3), Sample Recovery.

4. Place the acetone washing in a preweighed (to the nearest 0.1 mg) weighing bottle or equivalent. Measure the volume of acetone to the nearest ml. Evaporate the acetone at room temperature or over a water bath at slightly above room temperature. Desiccate until cool. Reweigh the container to the nearest 0.1 mg and determine the particulate weight by difference. Record the data on Form TLP.

5. Place the open, marked, weighing bottles from (2) above with their respective filters and/or thimbles in a drying oven at 105 °C; dry to constant weight. Remove the bottles and allow them to cool to room temperature in a desiccator.

6. Weigh each filter and thimble on a precision balance to the nearest one-tenth (0.1) milligram.

7. Measure a portion of the acetone stock used to wash out the particulate matter sample contact surfaces in the sampling train. Determine the weight of solids in this measured volume as described in (4) above for the acetone washing. Use at least 100 ml of the acetone stock for this analysis. Record the data on Form TLP: Laboratory Data Sheet (Particulate).

8. The blank analysis for the prefilter (if used) plus the blank analysis for the primary filter and acetone wash constitute the blank analysis for the test. One blank analysis for all runs in the test is acceptable provided the same type prefilters and primary filters are used for all runs, and the same stock of acetone is used for all runs. A run result is not acceptable if the sum of the changes in weight of the filter blanks is greater than 5% of the particulate matter sample weight collected for that run.

4.02. Condenser/Absorber Moisture (Weight/Volume).

a. Preparation for Field Use.

1. Thoroughly clean and dry all moisture container/

collector components and connecting tubing of the condenser. Place the components in a protective container for transport to the test site.

2. Fill the required number of absorbent containers (one or more per test run/sampling train) with dry desiccant material in a low humidity room. Secure the material in the containers in such a manner that loose material will not be pulled into the connecting tubing between the container and volume meter during sampling. Mark, weigh, and seal each container. Record the weight of each charged desiccant container to the nearest gram on Form TLH: Laboratory Data Sheet (Moisture).

b. Moisture Collected During Sampling.

1. Measure the moisture collected in the condenser to the nearest milliliter (ml). Record this value on Form TLH.

2. Clean the exterior of the desiccant cannister as necessary. Weigh the container to the nearest gram and record this weight on Form TLH.

4.03. Orsat Sample Analysis Description and Procedure.

a. Determine the percent by volume of Carbon Dioxide (CO_2), Oxygen (O_2), Carbon Monoxide (CO), and Nitrogen (N2) (by difference) in the composite Orsat sample if obtained, and in the obtained grab samples (3 per hour minimum) (see Sub-section 2.03 of this part) utilizing a standard Orsat analyzer or equivalent. If an alternate method or type of equipment is used, describe the methodology and equipment in detail.

b. The Standard Orsat Analyzer consists of:

1. A water jacketed burette - a graduated glass tube, enclosed in a larger glass tube filled with water. The burette is used to measure gas sample volumes. The water jacket is for maintaining a constant gas temperature.

2. Absorption pipettes - vessels which contain the selective absorbing reagents.

3. A manifold - a closed path for the gas between the burette and pipettes.

4. A leveling bottle - bottle containing the fluid used to effect the transfer of the gas between the burette and pipettes. See Figure 4-5. Orsat Sample Analyzer.

c. Obtain a measured sample in the burette.

1. See Sub-section 2.02 of this part, Preparation for Sampling.

2. Draw a 100 ml (or other convenient volume) gas sample into the burette, purging sufficient times to insure minimum contamination.

d. The three absorption pipettes are filled with specific reagents. The component gases must be removed from the burette sample in a specific order: CO_2, then O_2, then CO. Carbon Dioxide is absorbed by a Potassium Hydroxide (KOH) solution. This solution will also absorb H_2S, SO_2, and any other acid gases present. Oxygen is absorbed by an alkaline Pyrogallol solution, which will also absorb CO_2 in case it has not previously been absorbed. Carbon monoxide is absorbed by an acid cuprous chloride solution, which will also absorb O_2, if it has not been previously absorbed.

e. To determine the volume proportions of each component gas, the gas mixture is passed successively through each absorbing solution in the prescribed manner with volume readings being taken before and after each treatment. The difference in volume due to absorption represents the amount of a particular component in the mixture. All gas not absorbed is reported as nitrogen.

f. A number of precautions are necessary to obtain valid data: Use fresh reagents, keep the manifold clean and free of reagents, check the system for leakage, and be sure the leveling fluid is saturated with the sample gas before proceeding with the analysis. If mercury is used as the leveling fluid, maintain a water film on top of the mercury to keep the sample gas saturated. Consult the

manufacturer's guide and/or standard analytical texts for details of performing the analysis.

g. Record the obtained data and computational results on Form TOA: Laboratory Data Sheet (Orsat). See Part V., Section 3.00 for computations.

5.00. Heat Input Data Measurements.

5.01. General.

a. The data measurements required to determine the total heat input to the fuel burning unit(s) vented by the test stack during the test run period depends on the computational method applicable.

This procedure prescribes three (3) computational methods:

Method 1H - Fuel Use Basis
Method 2H - Steam Balance Basis
Method 3H - Flue Gas Analysis Basis

The test supervisor is to submit data on the heat input(s) based on the Fuel Use Basis (Method 1H) whenever coal scales or other fuel meters, as appropriate, are available.

If the appropriate fuel metering device(s) is not available, Method 2H - Steam Balance Basis is to be used.

For all test runs also submit data on the heat input(s) based on Method 3H - Flue Gas Analysis Basis, in addition to the data required by Method 1H or 2H, whichever is applicable.

b. The following Sub-sections detail the specific data required for each method and the means of obtaining these data.

5.02. Fuel Use Method (1H)

a. This computational method requires:

1. The measured amount of all fuel(s) fired in the fuel burning units during each test run period, as determined by continuous coal scales or equivalent and/or oil flow and/or gas meter(s). When gas is fired, the temperature and pressure of the gas meter(s) may be needed.

2. The average moisture, ash, volatile matter, and Btu value(s) of fuels fired in the fuel burning units during the test run period is determined as follows:

(a) For coal:

(1) Obtain a representative sample of the coal fired in each fuel burning unit during the test run period. This sample is to be obtained in accordance with the Commercial Sampling Procedure of ASTM Method: D492-48 "Sampling Coals Classified According to Ash Content" or its latest revision. Consult this ASTM standard for details of the required procedures. In this ASTM method, sampling procedures are prescribed for coal in four ash classifications. Each of these ash classifications is sub-divided into eight size groups. For each size group, these methods prescribe a minimum number of increments to be obtained, each of a minimum weight of gross sample. The procedure also prescribes the method of reducing this gross sample for analysis.

(2) Prepare the reduced gross sample, obtained above, for laboratory analysis in accordance with ASTM Method: D 2013-68, "Preparing Coal Samples for Analysis" or its later revision. Consult this ASTM standard for details of the required procedure. In this ASTM method, further amplification is given to the methods of reducing the gross sample to a laboratory sample and preparing the laboratory analysis. The laboratory sample is so prepared that 100% of the coal sample will pass through a No. 60 (250 micron) sieve. The final product is thoroughly mixed prior to extracting analytical samples.

(3) Extract an analytical sample from the laboratory sample and determine the moisture and ash content of this sample in accordance with ASTM Method: D271-70 "Laboratory Sampling and Analysis of Coal and Coke" or its latest revision. Consult this ASTM standard for details of the required procedures. In this ASTM method, procedures are prescribed for determining the moisture, ash, and volatile matter content of the sample. A one gram sample is placed in a preweighed open crucible. The sample is weighed at once and heated to 104-110 ^{o}C for one hour. The sample is then

cooled in a desiccator and reweighed. The moisture content is determined from the change in weights. The ash content is then determined by re-heating the dry sample from the moisture determination to a higher temperature (700-750 ^{o}C) in a muffle furnace until a constant weight is achieved. The ash content is then determined from the change in weight.

When the volatile matter content is needed (see Section 5.04 of this part), a one gram sample is placed in a covered platinum crucible, weighed at once, and then heated to around 950 ^{o}C for seven minutes. The sample is then cooled in a desiccator and reweighed. The volatile matter content is then determined from the change in weight minus the moisture as determined above.

(4) Extract another analytical sample from the laboratory sample and determine the Btu content of the sample in accordance with ASTM Method: D 2015-66 "Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter" or its latest revision. Consult this ASTM standard for details of the required procedure. In this procedure, the calorific value is determined by burning a weighed sample in an adiabatic oxygen bomb calorimeter under controlled conditions. The calorific value is computed from temperature observations made before and after combustion, taking proper allowances for thermometer and thermo-chemical corrections.

(5) Send a sealed and marked one pint sample of the laboratory sample, representative of the gross sample to the Commission with the test report. If drying was used in reducing the gross sample to the laboratory sample, indicate the percent loss of moisture during this process.

(b) For fuel oils:

Determine the supplier's name and address, and the

specifications for the oil supplied. Use the supplier's specifications when available for the ash content and Btu value of the oil. When such specifications are not available, determine the grade of oil fired, and use the data in the following table for the ash and Btu values. Send an eight ounce, sealed, marked, sample of the oil fired to the Commission with the test report.

TABLE 4-1. FUEL OIL ASH/BTU VALUES

Grade of Oil*	% Ash (wt.)	Btu/lb oil	lbs/gal
No. 1	---	19765	6.79
No. 2	---	19460	7.13
No. 4	0.05	18840	7.67
No. 5	0.05	18560	7.89
No. 6	0.25	18200	8.10

*Commercial Standard C S12-48, U. S. Dept. of Commerce.

(c) For Natural Gas:

Determine the supplier's name and address, and the specification of the natural gas supplied. Use the supplier's specification for the Btu value of the fuel. Ash may be considered negligible. If such specifications are not available, use the data in the following table for the natural gas Btu content.

TABLE 4-2. NATURAL GAS BTU CONTENT

Field	Btu/lb-Gas	Specific Gravity (related to air)
Pennsylvania	23170	0.636
S. California	22900	0.636
Ohio	22080	0.567
Louisiana	21820	0.600
Oklahoma	20160	0.630
Other (unless specific field data is available)	22030	0.614

(d) Other fuels:

Determine the name and address of the supplier(s) or producer(s) of any other materials fired during the test run period. Determine the source(s) of the fuel(s). Use the supplier(s)'/producer(s)' specifications for the ash, Btu value and theoretical air requirement (see Sub-section 5.04 of this part). When such specifications are not available, resolve with the Director or his designee, the method which will be used to determine these values, prior to conducting the test. Submit an appropriate small sample of the fuel fired, if other than a gas, to the Commission in a sealed, marked, sample container.

5.03. Steam Balance Method (2H).

This method requires a materials balance and inlet and outlet water/steam pressure and temperature data during the test run period, for the boiler(s) of the fuel burning unit(s) vented by the test stack.

a. Measure the mass flow rate of all water/steam flowing through each boiler.

b. Measure the inlet and outlet water/steam pressure and temperature of each water/steam circuit.

c. Construct a flow diagram of the water/steam flow circuit(s) on Form THI-II (2H). Record the measured data on this form, indicating the data points on the diagram.

d. Determine the boiler manufacturer's name and address, and the boiler type and model number. From the manufacturer's specification, determine the boiler thermal efficiency. If such specifications are not available, describe on Form THI-II(2H) the basis and method of selecting the value used.

5.04. Flue Gas Analysis Method (3H).

a. This method involves computing the amount of fuel fired from values of:

1. The total weight of stack gas discharged through the stack during the test run period;

2. The average excess air discharged through the test stack during the test run period;

3. The theoretical air to fuel ratio required to burn the type and quality of fuel fired; and

4. The ash fraction in the fuels fired.

The total heat input is then determined from the computed value of the amount of fuel fired and the average Btu value of the fuel. If more than one fuel is fired, the amount of stack gas attributed to the burning of all these fuels but one, is subtracted from the total amount of stack gas before computing the amount of other fuel fired (e.g., for a coal and oil fired unit, meter the oil fired, compute the stack gas, and determine the coal fired by difference).

b. Total Weight of Stack Gas.

The total weight of stack gas is determined from:

1. The stack velocity and temperature data obtained under Sub-section 2.03 of this part and recorded on Form TD: Test Run Data Sheet for each test run; and

2. The Orsat analysis data of the stack gas obtained under Part V, Section 3.00; and recorded on Form TOA - Laboratory Data Sheet (Orsat) for each test run.

c. Stack Excess Air.

1. For low nitrogen content fuel(s) (coal, fuel oil, natural gas), the stack excess air can be computed from the data obtained from the Orsat analysis described in Sub-section 4.03 of this part and recorded on Form TOA - Laboratory Data Sheet (Orsat) for each test run.

2. Note: If blast furnace gas, producer gas, or other fuel(s) of high nitrogen content are used, do not use the computational method for excess air described in Part V, Section 3.00 and item 20 of Form TOA:

Laboratory Data Sheet (Orsat). Consult the Director or his designee prior to conducting the test to determine and resolve a suitable method of determining the excess air when such fuel(s) are burned.

d. Theoretical Air Values.

1. For coal: the theoretical air required to burn a specific amount of coal can be computed from the Btu content, and data presented in Part V, Section 8.00, if the volatile matter content of the coal is greater than 10%(d. a. f.). If the volatile matter content of the coal is less than 10% contact the Director or his designee to resolve a suitable method.

2. For fuel oil and natural gas: the theoretical air to fuel ratio for fuel oil and natural gas may be computed when the Btu value of the fuel is known.

3. For other "fuels" consult the Director or his designee to determine and resolve a suitable means of determining the theoretical air to fuel ratio value for fuels other than coal, fuel oil, or natural gas.

e. Ash Content in Fuels Fired.

The percent ash in the coal fired is to be determined as prescribed in Sub-section 5.02 of this part.

Note: the Btu values and the ash contents are to be on an as fired basis. The volatile matter content values for coal to be on a dry ash-free basis.

Note: See Part V, Sub-section 8.04. Note the necessary moisture correction when the stack emissions are controlled with a scrubber or other wet media control equipment.

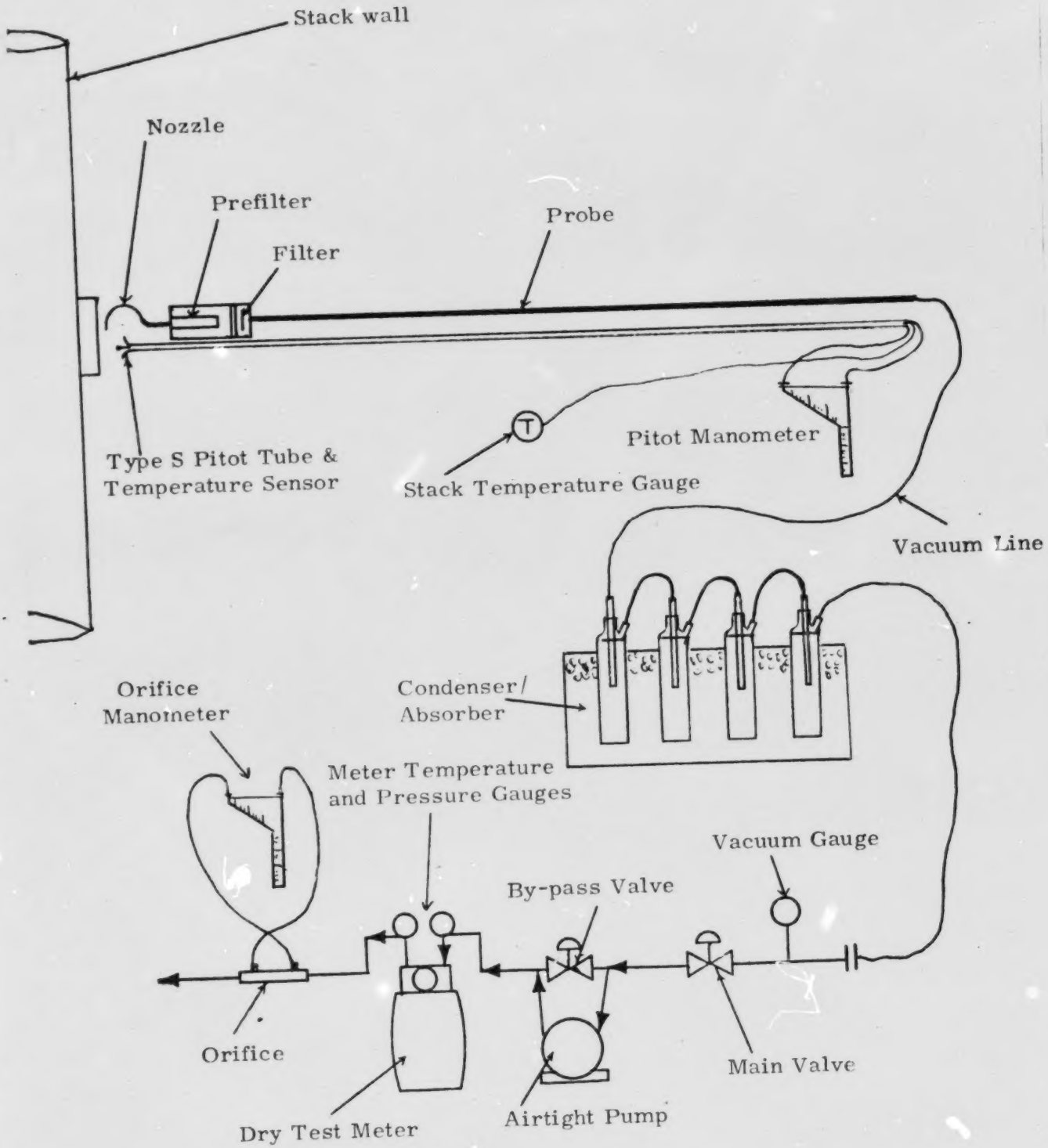


Figure 4-1a. Sampling Train Schematic.

One arrangement of an in-stack sampling train other arrangements are acceptable. See Part IV, Sub-section 2.01.

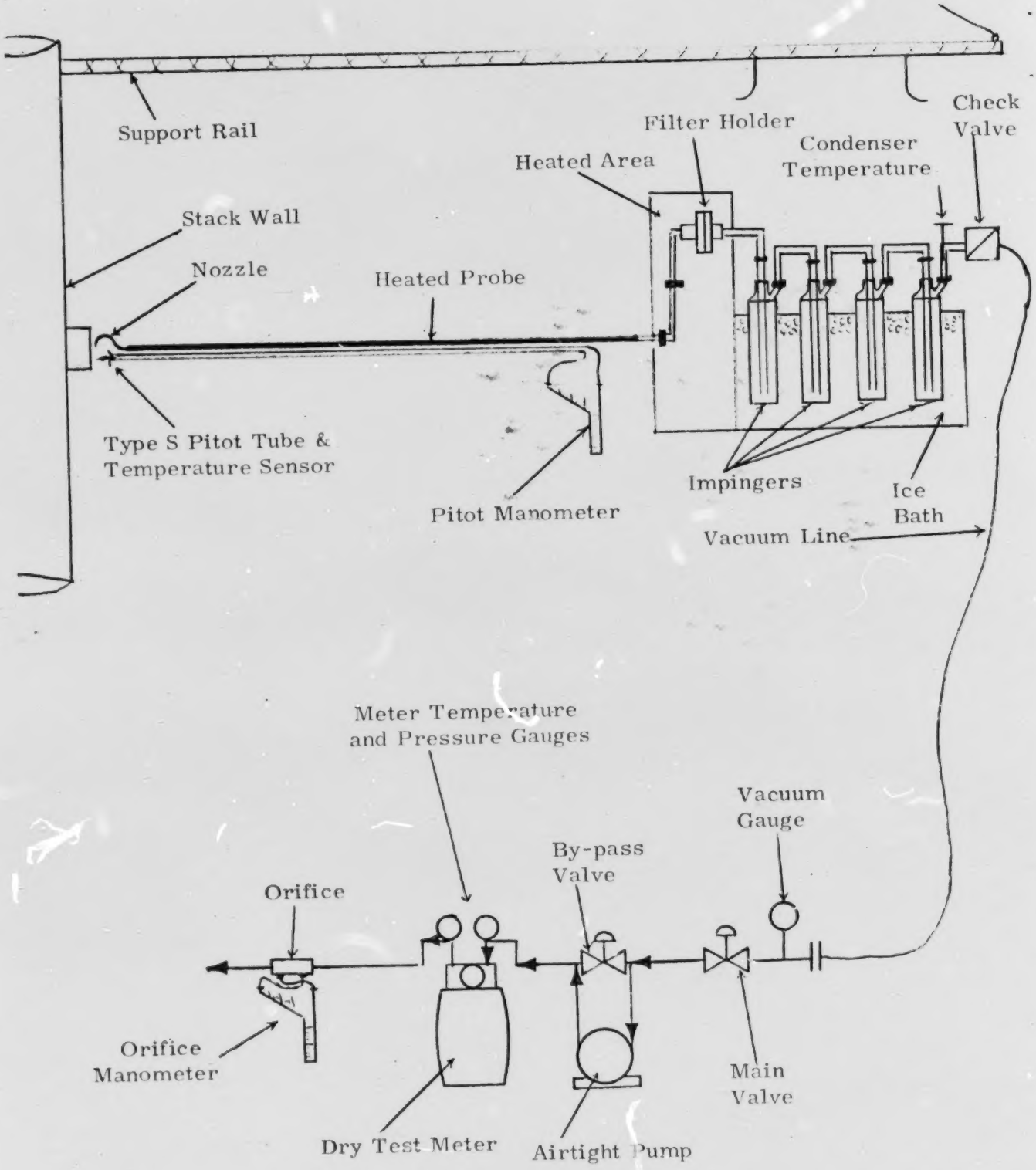
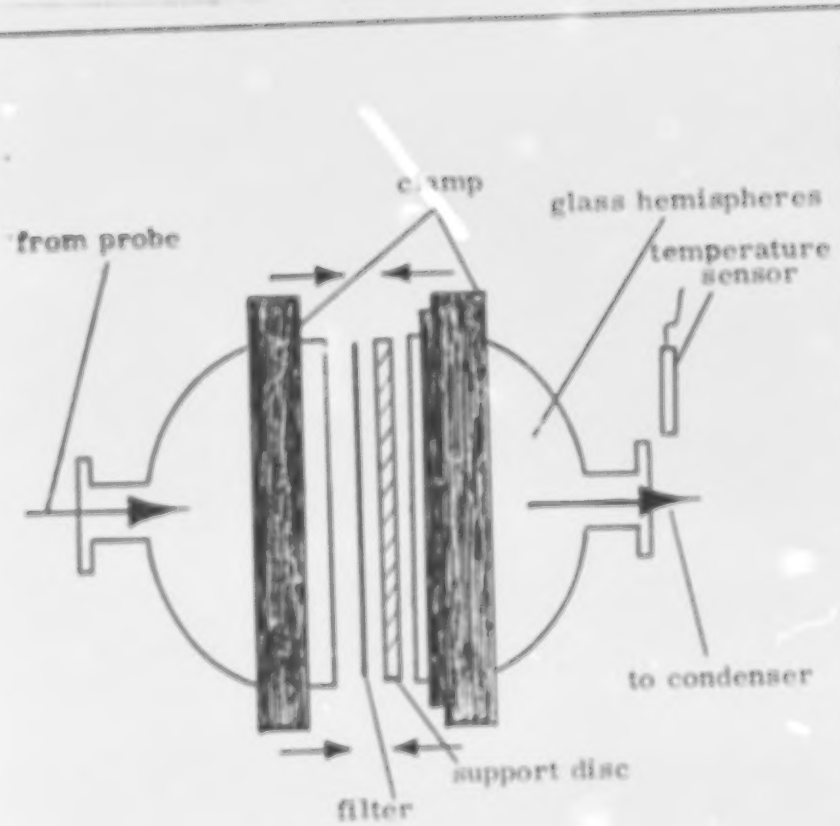


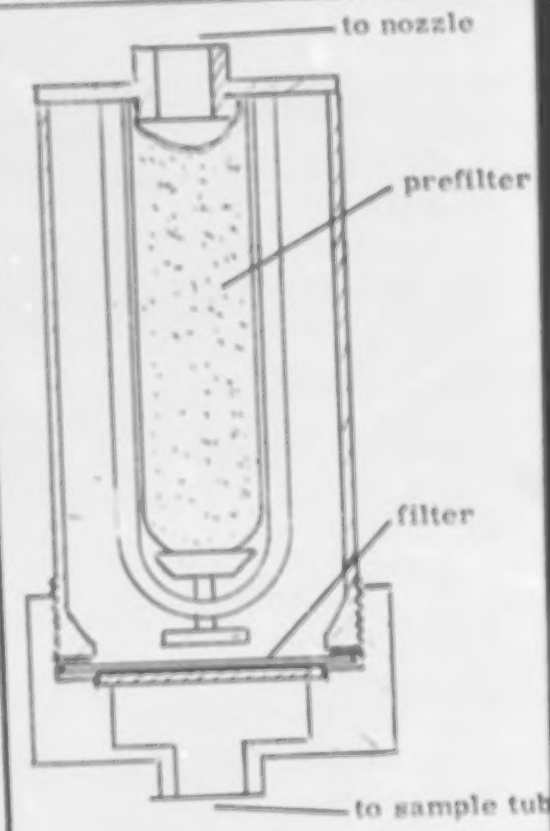
Figure 4 - 1b. Sampling Train Schematic.

One arrangement of an out-of-stack sampling train. Other arrangements are acceptable. See Part IV, Sub-section 2.01.

Figure 4-2. Sampling Nozzle.



Out-of-Stack Filter Holder.



In-Stack Filter Holder.

Figure 4-3 Filter Holder Assemblies.

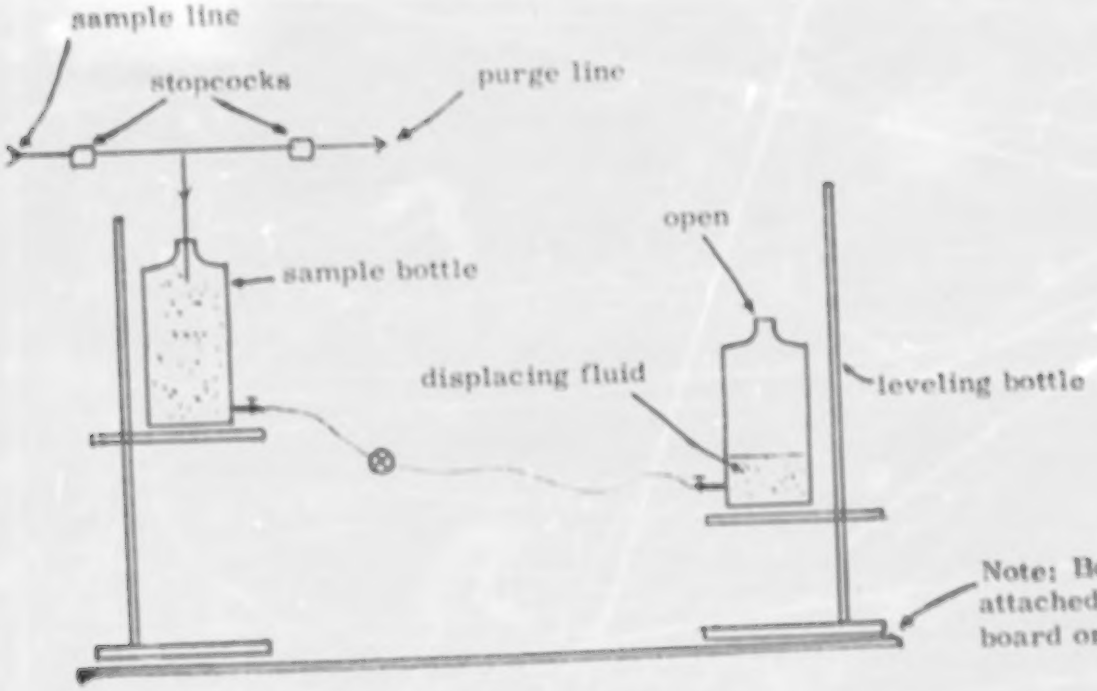


Figure 4-4 Composite Orsat Sample Device.

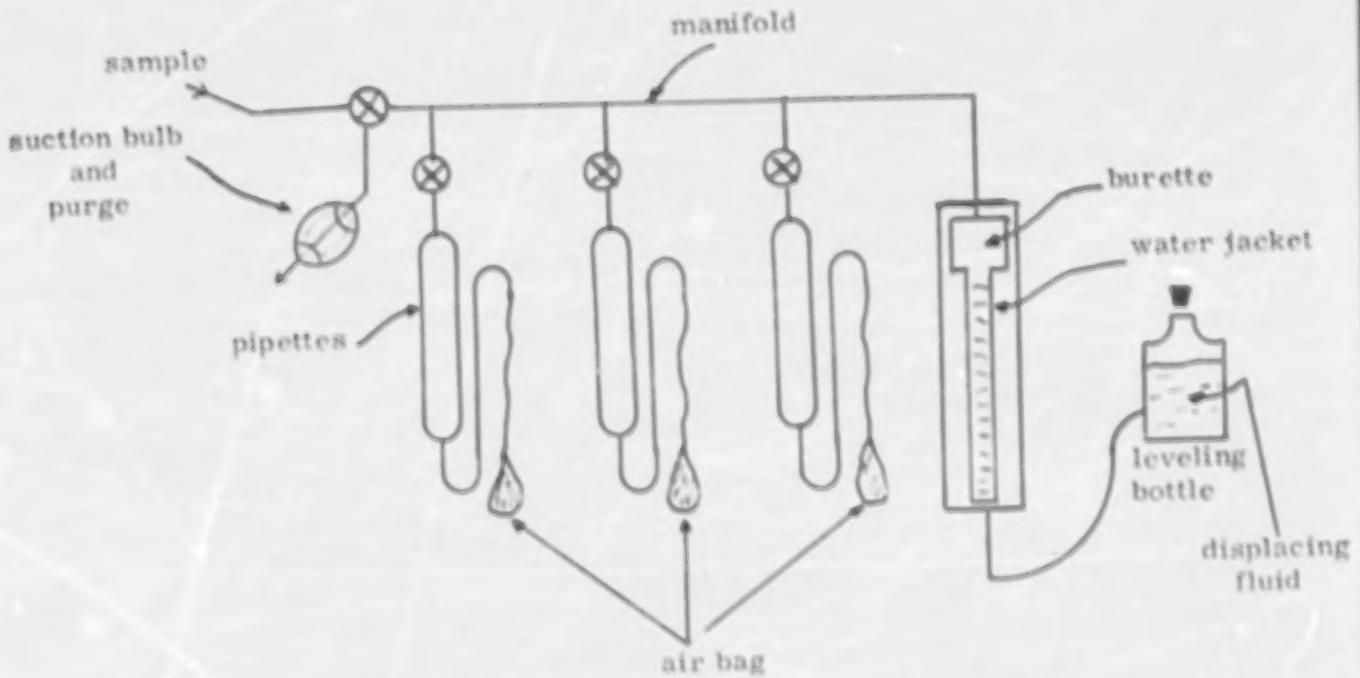


Figure 4-5. Orsat Sample Analyzer.

PART V. COMPUTATIONS AND DATA ANALYSIS

This part prescribes the computational method to be used in computing the particulate matter stack emission rate for the test and evaluating the supporting test data.

A. Test Run Data.

Perform the computations and analysis prescribed in this part for the data obtained from each test run which is to be part of the submitted test result. Record the measured data and the appropriate computations on the designated test report forms, a copy of which is at the Appendix. Submit sufficient commentary with the test report data to fully describe the conditions under which the data was obtained and any factors which might affect the evaluation of the test results.

1.00. Particulate Matter Sample Weight Determination. (Form TLP - Laboratory Data Sheet (Particulate).

Mf = particulate matter (in grams) collected by the primary filter, and the prefilter (if used)

Ma = particulate matter (in grams) obtained from the evaporation of the acetone washings of the internal sampling train surfaces exposed to the particulate sample prior to the primary filter

Ab = particulate matter residue (in grams) in the volume (Va) of acetone wash used for Ma above, as determined by the acetone blank analysis (i.e., Ab = (Sd) (Va); where Sd equals the solids found in the acetone blank analysis in gm/ml, and Va equals the volume of acetone used in the acetone wash for M_a above)

Mo = Mf + Ma - Ab = the indicated weight of particulate matter collected, in grams

s = the change in weight of the control filter(s) as determined by the filter blank analysis. Retain the sign of the net change.

m = Mo - s/2 = weight of particulate matter collected by the sampling train during the test run, in grams

r = s/Mo = relative uncertainty in the true value of m. If the absolute value of "r" is greater than .05 reject the run results.

2.00. Moisture Determination. (Form TLH: Laboratory Data Sheet - Moisture; Forms TD: Test Run Data Sheet).

Record all measured and calculated data on the appropriate forms. Compute and record the following:

Vm = (ft^3) the sum of all ΔDGR for the run, where ΔDGR is equal to the indicated amount of gas sampled at each point during the extraction interval

$\overline{Tm}$ = (^oF) average temperature of the dry gas meter during the test run. Tm = average dry gas meter temperatures (^oF) at each sampling point.

$\overline{Pm}$ = (in Hg) average absolute pressure at the dry gas meter during the test run. Pm = the average absolute pressure at the dry gas meter for each sample point, where Pm = Pb - Vac ; Pb = barometric pressure, Vac = meter vacuum.

Wc = (grams) amount of water collected in the condenser or impingers

Wd = (grams) amount of water collected by the drying agent used after the condenser or impingers

W = (grams) Wc + Wd

B = percent moisture in the sampled gas by volume on a wet basis, divided by 100

$$B = W \Big/ \left[\left[\frac{374\ \overline{Pm}\ Vm}{\overline{Tm} + 460} \right] + W \right]$$

w = moisture correction factor; ratio of the volume of wet sample gas to the volume of dry sample gas

w = 1 / (1 - B)

3.00. Sample Gas Density and Excess Air Determination.(Form TOA - Laboratory Data Sheet (Orsat).

3.01. Gas Density.

a. Record the Orsat analysis for all three runs on Form TOA (Laboratory Data Sheet) on lines 1 through 9. Compute and record the average value of the CO_2, O_2, CO and N_2 for each run on line 10 and the value of these components of the composite sample, if obtained (optional), on line 11.

b. Transcribe the values of w (moisture correction factor) from Form TLH to Form TOA in blocks 12 for each run. Transcribe the values of B, the percent water (wet basis) from Form TLH to Form TOA in column 13, line 14,for each run.

c. Correct the average component volumetric percentages,dry basis (line 10),to volumetric fractions (wet basis), by dividing by 100w and enter these values on line 14 for each test run.

d. Multiply each of these volumetric fractions (wet basis - line 14) by the corresponding molecular weights on line 15 and enter the values on line 16.

e. Enter the sum of the values of line 16 for each run in the appropriate box on line 17, the apparent molecular weight of the wet gas (Mg).

f. Determine the wet gas density for each run by dividing the molecular weight for that run (on line 17) by the number 29 and enter this quotient in the appropriate box on line 18. (Gd).

3.02. Excess Air.

Compute and record the excess air fraction for each run using the average dry gas analysis from line 10 and the formula shown on line 20. Record the excess air fraction (EA) in the appropriate box on line 19.

Note: The excess air fraction equation presented on line 20 of Form TOA is not applicable when producer gas, blast furnace gas or other fuels high in nitrogen content are used. See Part IV, Sub-section 5.04.

4.00 Actual Sample Gas Volume Determination. (Form TD: Test Run Data Sheet).

a. For each point sampled during the run compute the actual volume drawn through the sampling nozzle adjusted to standard conditions of 70 °F and 29.92 inches of Hg as indicated below:

q_m = Actual sample volume (in cubic feet) drawn through the sampling nozzle for each sampled point adjusted to 70 °F and 29.92 inches of Hg.

$$q_m = (\Delta DGR)(w)\left[\frac{530}{(Tm + 460)} \cdot \frac{Pm}{29.92}\right]$$

WHERE,

ΔDGR, w, Tm, and Pm are defined in Section 2.00 of this part and are recorded on Form TD,

b. Record the computed values of q_m for each sampled point on the appropriate line of the column labeled q_m on Form TD. Sum the values of q_m for all points included in the run and enter this value (Qm) in the block so labeled.

5.00. Isokinetic Sample Volume Determination. (Form TD: Test Run Data Sheet).

a. For each point sampled during the run, compute the volume of sample gas (adjusted to 70 °F and 29.92 inches of Hg) that would have been drawn through the sampling nozzle if isokinetic conditions were maintained, as indicated below:

q_o = Isokinetic sample volume, the volume of sampled gas (in cubic feet) for each sampled point, if isokinetic conditions were maintained, adjusted to standard conditions of 70 °F and 29.92 inches of Hg

$$q_o = 60(Fp)(An)\left[\sqrt{\Delta H\,(Ts+460)\,\frac{29.92}{Ps}\cdot\frac{1.00}{Gd}}\right](\Delta t)\left[\frac{530}{Ts+460}\right]\cdot\left[\frac{Ps}{29.92}\right]$$

WHERE,

Fp = combined correction factor for units and Pitot tube deviation:

Standard tube = 2.90 (units) x 1.00 (deviation) = 2.90

Type S tube = 2.90 (units) x 0.83*(deviation) = 2.41

*Note: The deviation for the Type S tube may vary for different sampling configurations and should be determined by calibration against a standard pitot tube for each Pitobe arrangement. See Part IV, Section 2.02, Preparation for Sampling.

A_n = the cross-sectional area of the sampling nozzle in square feet

ΔH = Pitot tube differential reading** in inches of H_2O (water)

**Note: If the particular pitot tube differential indicator used is calibrated to give a reading of the square root of ΔH ($\sqrt{\Delta H}$), change the heading of the "ΔH" column on Form TD to $\sqrt{\Delta H}$ and modify your computations for q_o as appropriate.

Ts = Average stack gas temperature (in ^oF) at each sampled point during the extraction time at that point

Ps = Average static pressure*** (in inches of Hg) in the stack during the run

***Note: Ps may normally be assumed to be equal to the ambient (barometric) pressure (Pb), unless a venturi type stack is being sampled.

Gd = Gas Density Correction Factor, defined in Section 3.00 of this part

All required values for computing q_o are recorded on Form TD.

b. Record the computed values of q_o for each sampled point on the appropriate line of the column labeled q_o on Form TD. Sum the values of q_o for all points included in the run and enter this value (Q_o) in the block so designated.

6.00. Fractional Isokinetic Rate Determination. (Form TD: Test Run Data Sheet).

a. For each point sampled during the run, compute the point isokinetic factor (ISKp), which indicates the average degree of deviation from isokinetic conditions during the sampling (extraction) time at that point. ISKp is computed as follows:

ISKp = the point isokinetic factor, the ratio of the actual sample volume to the isokinetic sample volume, both volumes adjusted to standard conditions of 70 ^{o}F and 29.92 inches of Hg

$$ISKp = \left[\frac{q_m}{q_o}\right]$$

WHERE,

q_m is defined in Section 4.00 of this part and q_o is defined in Section 5.00 of this part, both values are recorded for each point on Form TD.

b. Record the computed values of ISKp for each sampled point on the appropriate line of the column labeled ISKp on Form TD. The value of ISKp for each sampled point should not vary greatly from the overall isokinetic factor for the run ISK_o.

c. For each run, compute the overall isokinetic factor (ISK_o), which indicates the overall degree of deviation from isokinetic conditions during the run, and which is used in the weight emission rate computations of the next section. ISK_o is computed as follows:

ISK_o = the overall isokinetic factor, the ratio of the total actual sample volume to the total isokinetic sample volume, both volumes adjusted to standard conditions of 70 ^{o}F and 29.92 inches of Hg

$$ISK_o = \left[\frac{Qm}{Qo}\right]$$

WHERE,

Qm is defined in Section 4.00 of this Part and Qo is defined in Section 5.00 of this part, both values are recorded for each run on Form TD.

d. Record the computed value of ISKo for each run in the block so designed on Form TD. If the value of ISKo is outside the range of 0.9 to 1.10, reject the run result.

e. Compute the value %ISK as follows: retain the sign and record on Form TR-II: Summary of Test Run Results.

$$\%ISK = 100 \left[ISKo - 1\right]$$

7.00. Particulate Matter Emission Rate Determination. (Form TD: Test Run Data Sheet: Form TR-II: Summary of Test Run Results).

7.01. The particulate matter emission rate for each run is computed from the following equation:

$$M(P)_n = \frac{m}{C} \cdot \frac{As}{An} \cdot \frac{60}{\Theta} \cdot \frac{1}{ISK_o}$$

WHERE,

M(P)n = the particulate matter emission rate (in pounds per hour) for the test run

m = $M_o - s/2$ = weight of particulate matter collected by the sampling train (in grams). See Section 1.00 of this Part.

C = 453.592 grams/pound

As = the cross-sectional area of the sampling plane in square feet

An = the cross-sectional area of the sampling nozzle in square feet

60 = 60 minutes per hour

Θ = the sum of all extraction times at all points sampled per run. The sum of Δt's. The total sampling time, not including movement time from port to port.

ISK_o = Qm/Qo = the overall isokinetic factor for the run. The ratio of total actual volume sampled to the total isokinetic volume, both values adjusted to 70 °F and 29.92 inches of Hg on a wet basis. (See Sections 4.00, 5.00, and 6.00 of this part)

The values of m, As, An, Θ, and ISK_o for each run are recorded on Form TD: Test Run Data Sheet.

Record the value of M(P)n for each test run on Form TR-II: Summary of Test Run Results.

7.02. If more than one sampling plane was required to evaluate the total stack emission rate, perform the computation specified in 7.01 for each sampling plane, then sum the values of M(P)n for all sampling planes used. Record the total emission rate for each run (all sampling planes) on Form TR-II as above, then compute the average stack emission rate for the test. (See Sub-Part B. Test Results) Note the number and designations of the sampling planes used under comments. If more than one sampling train was used simultaneously, to sample the required number of sampling points at one sampling plane the values of m, Qm, and Qo are the sum total values for all the sampling trains used for the one sampling plane.

8.00. Heat Input Determinations.
(Forms THI-II: Heat Input Data Sheets: Form TOA: Laboratory Data Sheet(Orsat); Form TR-II: Summary of Test Run Results).

8.01. General.

a. This section prescribes three (3) methods of computing the total heat input to the (similar) fuel burning unit(s) vented by the test stack:

Method 1H - Fuel Use Basis
Method 2H - Steam Balance Basis
Method 3H - Flue Gas Analysis Basis

Submit data and computations on the appropriate forms.

b. Summarize the results of the selected computational methods on Form TR-II: Summary of Test Run Results for each run. Record the type units tested (see definitions for type), the total number of similar units associated with the test run results, the two values of the total heat input for all the units associated with the test run result, as computed by the two selected methods, the total design heat input and the total maximum normal operating load for the units associated with the test result (see definitions for the heat input terms).

8.02. Method 1H - Fuel Use Basis.

a. From the data obtained in accordance with Part IV, Section 5.02, Heat Input Data Measurements, compute the heat input for each fuel burning unit for which this method is to be used, as follows:

$$HI = \frac{60}{\Theta} \sum_{i=1}^{n} \frac{(Fi \times HV_i)}{10^6}$$

WHERE,

HI = Heat input per fuel burning unit(s) in 10^6 Btu per hour

Fi = The quantity of each fuel fired in this fuel burning unit during the total test run period (Θ) in appropriate dimension units (e.g., pounds, gallons, SMCF)

HV_i = The average Btu value of each fuel used, in appropriate dimensional units related to the F_i units (e.g., Btu/lb, Btu/gal, Btu/SMCF), on an as fired basis

Θ = The total test run period in minutes. The sum of all extraction intervals (Δt)

n = The number of different fuels fired in the fuel burning unit during the test run period

NOTE: When more than one fuel burning unit is vented by the test stack, sum the individual Heat Input values for all units of the same type vented by the test stack to obtain the total heat input for the test.

b. Record the values used in the computations, and the results on Form THI-II (1H).

8.03. Method 2H- Steam Balance Basis.

a. From the data obtained in accordance with Part IV, Section 5.03, Heat Input Data Measurements, compute the heat input for each fuel burning unit for which this method is to be used, as follows:

$$HI = \frac{mf\ (ho - hi)}{10^4\ (BE)}$$

WHERE,

HI = Heat input per fuel burning unit in 10^6 Btu per hour

ho = Average enthalpy of steam/water leaving the boiler of the fuel burning unit in Btu/lb

hi = Average enthalpy of steam/water entering the boiler of the fuel burning unit in Btu/lb

mf = Average mass flow rate of steam through the boiler in lb/hour

BE = The boiler thermal efficiency in percent

NOTE: The enthalpy values for the above equation can be determined from the inlet and outlet temperatures and pressures of the steam/water flowing through the boiler using appropriate steam tables.

b. Record the steam flow, temperatures, pressures, and enthalpy values on the steam circuit flow diagram required on Form THI-II (2H) by Part IV, Section 5.03. Also record the necessary calculations and results on Form THI-II (2H) or attached sheet(s). Sum the heat input values of all fuel burning units of the same type vented by the test stack.

8.04. Method 3H - Flue Gas Analysis Basis.
(See Part IV, Sub-section 5.04)

a. Compute the total weight of stack gas discharged through the test stack during the test run period on Form THI-II (3H) as follows:

$$AFG = \frac{(Q_o)\ (C_o)\ (Gd)\ (A_s)}{A_n} - W_h$$

WHERE,

AFG = total weight of stack gas discharged through the test stack (in lbs) minus moisture attributable to sources other than the combustion of fuel in the tested units

Q_o = the total isokinetic sample volume in cubic feet recorded on Form TD (see Part V, Section 5.00)

C_o = 0.07492, the weight in pounds of one cubic foot of air at 70 °F and 29.92 inches of Hg

G_d = the stack gas density correction factor, dimensionless, recorded on Form TOA (see Part V, Section 3.00)

A_s = the cross-sectional area of the stack in square feet; recorded on Form TD

A_n = the cross-sectional area of the sampling nozzle, in square feet; recorded on Form TD

W_h = the total pounds of water vapor present in the total volume of stack gas emitted during the test run period (Θ) in addition to that produced by the burning of fuel(s)

W_h = Ws + Wa; Note: if water is not injected into the gas stream prior to the sampling site, Ws = O

Where,

Ws = the total pounds of water vapor added to the effluent stack gas stream during the test run period (Θ) by a scrubber or other water media pollutant collection or quenching device

$$Ws = Was - Wbs$$

Where,

Was = the total pounds of water present in the total volume of stack gas after the scrubber or other similar device

$$Was = \frac{B\ Q_o\ As}{21.483\ An}$$

Where, B, Q_o, As, An have been previously defined. See forms TD and form TLH.

Wbs = the total pounds of water present in the total volume of stack gas prior to the scrubber or other similar device.

$$Wbs = \frac{B^*\ Q_o^*\ As^*}{21.483\ An^*}$$

Where, the values of B*, Qo*, As*, An* are the values determined at an appropriate moisture sampling plane prior to the scrubber.

Note: if Ws is not equal to zero (0), consult the Director or his designee before using this method.

Wa = the total pounds of water vapor present in the effluent stack gas due to moisture in the ambient air

$$Wa = \frac{Qo}{w} \cdot \frac{As}{An} \cdot \frac{Ba/100}{21.483}$$

Where, Qo, w, As, An, have previously been defined; an

Ba = the percent (by volume) moisture in the ambient air as determined by a wet-bulb and dry-bulb thermometer and a psychrometric chart for air-water mixtures at 29.92 inches of Hg (Dry Basis)

21.485 = ft^3 per lb of H_2O vapor at 70 ^oF and 29.92 in Hg

b. Compute the theoretical air requirements of each fuel burned from the following general equation using the appropriate values of Cf listed below, and the Btu values of the fuel as determined in Part IV, Section 5.03.

$$THA_f = C_f \left[\frac{HV_f}{10,000}\right] \cdot \frac{\text{lbs-air}}{\text{lbs-fuel}}$$

C_f = A conversion constant for the particular type fuel burned:

C_f - for coal(V.M.> 10% d.a.f) = 7.60
C_f - for fuel oil = 7.45
C_f - for natural gas = 7.20
(for other fuels and coal with less than 10% V.M. (d.a.f. basis) consult the Director or his designee to determine a suitable value)

HV_f = the heating value of the fuel (in Btu/lb) on an as fired basis

c. If more than one type of fuel is burned in any of the fuel burning units vented by the test stack, select the one not to be directly measured (most likely coal), and compute the weight of stack gas attributable to the burning of the other fuel(s), on Form THI-II (3H) as follows:

$$\text{WHERE, } AFG_o = \sum_{i=1}^{n} (X_f - P_f)_i \ (w_f)_i$$

AFG_o = total weight of stack gas vented through the test stack during the test period, in lbs, which is attributable to the burning of all fuels but the one not metered

X_f = THA_f (1 + EA) + 1; where THA_f is the theoretical air of the fuel "f", defined above, in terms of lbs-air/lbs-fuel; and EA is the stack excess air fraction recorded on form TOA, (see Part V, Section 3.00)

P_f = the ash fraction in fuel "f" on an as fired basis

w_f = the total measured weight in lbs of fuel "f" fired in all fuel burning units vented by the test stack during the test period

n = the number of different fuels fired in all fuel burning units vented by test stack during the test period, minus the one not metered

d. Compute the value X_f of the fuel not metered. Record this value and the ash content fraction of this fuel on Form THI-II (3H).

e. Compute the amount of the non-metered fuel fired, on Form THI-II (3H) as follows:

$$W_{cf} = \frac{AFG - AFG_o}{X_{cf} - P_{cf}}$$ = Weight (in pounds) of the non-metered fuel fired

WHERE,

AFG = the total weight of stack gas as defined above.

AFG_o = the total weight of stack gas attributable to the burning of other fuels, as defined above

X_{cf} = X_f for the non-meter fuel; equal to THA_{cf} (1 + EA) +1 as defined above

P_{cf} = the ash fraction of the non-metered fuel (e.g., coal)

f. Enter the computed value of W_{cf} in the appropriate column of form THI-II (1H), placing an asterisk beside the value. List the heating value of this fuel in the appropriate column of form THI-II (1H), along with the measured amounts and

heating values of the other fuels fired. Compute and sum the heat input attributable to each fuel in all similar type fuel burning units vented by the test stack on Form THI-II (1H).

B. Test Results.

Compute the arithmetic mean of the particulate matter emission rates for the three runs and record this value (in pounds per hour) on Form TR-II: Summary of Test Run Results in the block labeled Test Result - $M(P)_o$.

Also record (on Form TR-II) the date and time each run began, the total sampling time (Θ), and number of points sampled for each run.

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APPENDIX A: TEST REPORT FORMS

These Forms are designed to be used with the Commission's Technical Publication TP-2 "Particulate Matter Stack Emission Compliance Test Procedure". Consult that publication for information on completing and filing the enclosed forms:

Form	Form Designation
COVER SHEET	
IDENTIFICATION SHEET	TI
SUMMARY OF TEST RUN RESULTS	TR(II)
SAMPLING SITE DATA SHEET	SSD
TEST RUN DATA SHEET	TD
LABORATORY DATA SHEETS	
(Particulate)	TLP
(Moisture)	TLH
(Orsat)	TOA
(Fuels)	TAF
HEAT INPUT DATA SHEETS	
Fuel Use Basis (1H)	THI-II(1H)
Steam Balance Basis (2H)	THI-II(2H)
Flue Gas Analysis Basis (3H)	THI-II(3H)

APPENDIX B: BIBLIOGRAPHY

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STACK TEST REPORT

Facility _____

Unit(s) _____

Stack _____

Conducted by

_____

Under Regulation _____

Submitted on _____

to the

STATE OF WEST VIRGINIA

AIR POLLUTION CONTROL COMMISSION

Subject: STACK TEST REPORT

TEST NUMBER

To:

West Virginia Air Pollution Control Commission
1558 Washington Street, East
Charleston, West Virginia 25311

(For WVAPCC Use Only)

IDENTIFICATION

1. Facility

   A. Parent Organization _____

   B. Facility Name _____

   C. Facility Address/ Location _____

   _____

   D. Individual to Contact Regarding this Report:

      Name _____

      Title _____

      Address _____

      Telephone _____

   E. Source Operation Tested _____

   _____

   F. Type of Control Equipment _____

   _____

   G. Stack Designation _____

TEST SUPERVISOR (type)	(Signature)	(Date)

Stack Test Report

Test #

SUMMARY OF TEST RUN RESULTS (TR-II)

	Stack Designation*		
Type Units Vented by Stack (circle)--------	a	b	c

	Run #1	Run #2	Run #3
Number of Units Vented by Stack----------			
Total Heat Input (MMBtu/hr) - Method 1H--			
Total Heat Input (MMBtu/hr) - Method 2H--			
Total Heat Input (MMBtu/hr) - Method 3H--			
Normal Max Operating Load (MMBtu/hr)--			
Total Design Heat Input (MMBtu/hr)-------			
Total Coal Fired (pounds) ----------			
Average Percent Ash (coal)----------			
Total Oil Fired (gallons) No. _____ Oil-----			
Total Gas Fired (MCF)----------			
Other _____( )----			
Date Run Began----------			
Time Run Began----------			
Length of Run, minutes (θ)----------			
Number of Points Sampled----------			
Percent Isokinetic Conditions: %ISK-------			
Total Sample Volume (Qm) (ft^3)----------			
Percent Moisture: (B x 100)----------			
Particulate Matter Emission Rate (lbs/hr)-			
Test Result----------	M(P)o = _____ lbs/hr		
For WVAPCC Use Only----------			

Comments:

*As registered with the Commission under Regulation II.

Stack Test Report

Test #

SAMPLING SITE DATA SHEET	Site Identification Number
Sampling Plane Schematic: (Show crossectional dimensions, port and point locations, deposit buildup, etc.)	Point Sampling time (Δt):
	(1) As: ft^2
	(2) Nearest Upstream Disturbance: Dia's
	(3) Nearest Downstream Disturbance Dia's
	(4) For Rect. Ducts: Equal Areas 1/w ratio:

Minimum Required No of Points**

By Item	No Points	Ck
(1) (As/12)		
(2) See Fig. 3-1		
(3) See Fig. 3-1		

Diameter or Equivalent Diameter*:

Sampling Site Layout. (Show dimensions, general arrangement, bends, baffles, disturbances, with respect to the sampling plane.)

*Eq Dia = 2 (length) (width)/(length + Width) ; for Rectangular Ducts.

**Part III, Particulate Matter Stack Emissions Compliance Test Procedure, TP-2 (WVAPCC)

Stack Test Report Test #

Continuation:

Stack Test Report

TEST RUN DATA SHEET

Test # Run #

F_p =		Ps =	Gd =	As =	An =	m =
Θ =		Pb =				w =

Sampling Train Identification:

TEST Time*	TEST Point	Δt	ΔH	T_s	DGR	ΔDGR (calc.)	T_m	Vac	T_f	P_m (calc.)		qm (calc.)	qo (calc.)	ISK_p (calc.)

Stack Test Report

Test #

TEST RUN DATA SHEET (Continuation)

Run #

TEST Time*	Point	Δt	ΔH	T_s	DGR	ΔDGR (calc.)	T_m	Vac	T_f	P_m (calc.)		q_m (calc.)	q_o (calc.)	ISK_p (calc.)

LABORATORY DATA SHEET
(Particulate)

Test #:

ITEM/IDENTIFICATION

WEIGHT (GRAMS)

	Run # 1	Run # 2	Run # 3	Blank(s)	
(1) Pre-filter					After
					Tare
IDN R 1 R 2 R 3 B (1)				(c)	Change
(2) Primary Filter					After
					Tare
IDN R 1 R 2 R 3 B (2)				(d)	Change
Mf = sum of (1) & (2)					
(3) Acetone Wash					After
					Tare
IDN R 1 R 2 R 3 B Ma				(a)	Change
				(b)	Wash Volume (ml)
Sd = (a)/(b) Va =					
Sd = gm/ml					
Ab = (Va)(Sd) =					
Summation					
Pre-filter (1) =				(c)	
Primary Filter (2) =				(d)	
Acetone Wash Ma =				(c) + (d)	
Sub-total =				s	
-Ab					
Mo =				s/2	
m = Mo-s/2 →					
r = s/Mo →					

Laboratory Official (type)	(Signature)	(Date)

APCC/72 - TLP

Stack Test Report

LABORATORY DATA SHEET
(Moisture)

Test #

ITEMS / IDENTIFICATION

WEIGHT(gms)/ VOLUME*(ml)

(1) Impingers/Condensers

IDN	R 1	R 2	R 3

Wc =

	Run #1	Run #2	Run #3
after			
tare			
change			

(2) Desiccant Containers

IDN	R 1	R 2	R 3

Wd =

	Run #1	Run #2	Run #3
after			
tare			
change			

(3) Summation: W = Wc + Wd =

Run #1	Run #2	Run #3	
			TOTAL GRAMS

(4) $B = W / \left[\left(374 (\overline{Pm}) (Vm) / (\overline{Tm} + 460) \right) + W \right]$

Run #1: B = ( )/ [(374 ( ) ( )/( )) + ( )] =

Run #2: B = ( )/ [(374 ( ) ( )/( )) + ( )] =

Run #3: B = ( )/ [(374 ( ) ( )/( )) + ( )] =

(5) $w = 1/(1-B)$

w = moisture correction factor =

Run #1	Run #2	Run #3

*1 ml equivalent to 1 gram at room temperature.

LABORATORY OFFICIAL (type)	(Signature)	(Date)

Stack Test Report

LABORATORY DATA SHEET (Orsat)						Test #													
Run #1 Date % By Volume, (Dry Basis)						Run #2 Date % By Volume, (Dry Basis)						Run #3 Date % By Volume, (Dry Basis)							
	Time	CO_2	O_2	CO	N_2	Time	CO_2	O_2	CO	N_2		Time	CO_2	O_2	CO	N_2	
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10	Ave					Ave						Ave					
11	Comp					Comp						Comp					
12	w =				(13) (B)	w =				(13) (B)		w =				(13) (B)	
% by volume (Wet Basis)						% by volume (Wet Basis)						% by volume (Wet Basis)					
	CO_2	O_2	CO	N_2	H_2O	CO_2	O_2	CO	N_2	H_2O		CO_2	O_2	CO	N_2	H_2O	
14																	
15	44	32	28	28	18	44	32	28	28	18		44	32	28	28	18	
16																	
17	MOL WT =		= Mg				= Mg						= Mg				
18	Mg/29 =		= Gd				= Gd						= Gd				
19			= EA				= EA						= EA				

20 WHERE EA* = $$\frac{(\%O_2) - (\%CO/2)}{0.264(\%N_2) - (\%O_2) + (\%CO/2)}$$

*Not applicable when producer gas, blast furnace gas, or other fuels high in N_2 are used. See Part IV, Sub-Section 5.04

LABORATORY OFFICIAL (Type)	(Signature)	(Date)

Stack Test Report

LABORATORY DATA SHEET (Fuels)

Test #

Sample Number	Fuel Sampling Data: Gross Sample lbs	Fuel Sampling Data: Increments (No.)	Fuel Sampling Data: Laboratory Sample lbs	Type Fuel	Fuel Quality Data: Moisture as received % by Wt	Fuel Quality Data: Ash as received % by Wt	Fuel Quality Data: Volatile Matter (d. a. f.) % by Wt	Fuel Quality Data: Btu Content as received Btu/lb	Fuel Quality Data: Prior* Surface Moisture lost (%)
Run #									
Run #									
Run #									

TEST SUPERVISOR (type)

(Signature)

LABORATORY OFFICIAL (type)

(Signature)

(Date)

* Note surface moisture lost during reduction of gross coal sample to laboratory sample in percent (%), as applicable.

APCC/72 - TAP

Page ___ of ___

Stack Test Report — Test #

HEAT INPUT DATA SHEET - III (Fuel Use Basis)					Run #	
Number and *Type* Unit	Type Fuel	Ash P_i	Fuel Fired F_i (pounds)	Heating[1] Value(HV)[illegible] (Btu/lb)	Heat[2] input (HI) 10^6 Btu/hr	Sample No. ***
Totals**						
a						
b						
c						

P_i = ash fractions

1. as fired
2. HI = $\frac{60}{64} \sum (F_i \times HV_i)$

* Type a, b, c; see definitions. List all fuels fired under each unit designation before listing the next unit.

** List the total heat input for each type unit separately. If Method IIB, 2II, or 3II were used in combination to determine the Heat Inputs explain the method of prorating the heat input between the different type units as applicable. (Use additional sheets as necessary.)

*** As listed on Form TAF, Laboratory Data Sheet (Fuels).

64 = min.

PROCESS OBSERVER (type)	(Signature)	(Date)

APCC/72-TH-II (III)

HEAT INPUT DATA SHEET - 2H (Steam Balance Basis)	Run #
	BE:
Heat Input for all fuels fired in this unit during the test run period: 10^6 Btu/hr	Type Fuel Burning Unit a b c
	Θ =

Unit Designation:

Schematic Flow Diagram and Computations:

Note: Use additional blank sheets as necessary. Record the Heat Input for this unit in the appropriate column of Form THI-II (1H).

Test #

HEAT INPUT DATA SHEET - 2H (Steam Balance Basis)	Run #

Continuation:

Stack Test Report

Test #

HEAT INPUT DATA SHEET - 3H
(flue gas analysis basis)

Run #

1. $AFG = \frac{(\quad)(\quad)(\quad)(\quad)}{(\quad)} - W_h(\quad)$

A_s Q_o C_o G_d A_n

$W_h = W_s + W_a$; See Part V, Sub-Section 8.04 Particulate Matter Stack Emission Compliance Test Procedure TP-2, use additional sheets as necessary.

AFG = _____ lbs. (1 + EA) = _____

2. Fuels Fired	C_f	$HV_f/10,000$	THA $\frac{\text{lbs - air}}{\text{lbs - fuel}}$
**			
*			
*			
*			
*			
*			
*			

3. Fuels Fired	X_f	P_f	W_f	AFGf
**				
*				
*				
*				
*				
*				
*				

* metered fuels
** fuel not metered (cf)

AFG_o = _____

4. $W_{cf} = \frac{(\quad) - (\quad)}{(\quad) - (\quad)}$

AFG AFG_o X_{cf} P_{cf}

W_{cf} = _____ lbs. θ = _____ min.

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